A

READER IN BOTANY.

Part II.

FLOWER AND FRUIT.

SELECTED AND ADAPTED FROM WELL-KNOWN AUTHORS.

BY

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A READER IN BOTANY.

I.

CROSS-FERTILIZATION.

In 1793, at Berlin, was published a book entitled, "Nature's Secret in the Structure and Fertilization of Flowers Unveiled."[1] It is a charming old book with a dainty, flowery title-page, sprinkled with fluttering insects (Fig. 2), as unlike a grave scientific work of the eighteenth century as can well be imagined. A celebrated German professor says that as a child he used to amuse himself with the plates, regarding the book in the light of a fairy tale. Such it was for a long time held to be, though now we know it was the first discovery of a real secret of Nature. Let us hear how the author of the book, Christian Conrad Sprengel, came to make his discovery.

"In the summer of 1787," he begins his preface, "when I was looking attentively at the flower of

[1] "Das Entdeckte Geheimniss der Natur im Bau und in der Befruchtung der Blumen," by Christian Conrad Sprengel. Berlin, 1793.

the Wild Geranium, *Geranium sylvaticum* (Fig. 1), I found that the bases of the petals on the inner side and on both edges were furnished with fine, delicate hairs. Convinced that the wise designer of Nature had not created a single hair in vain, I considered what purpose they might serve, and it soon occurred to me that if we suppose the five

FIG I GERANIUM SYLVATICUM ("Pflanzenleben.")

drops of nectar, secreted by as many glands, to be intended for the nourishment of certain insects, there is nothing improbable in this nectar being protected from the rain, and the hairs might be placed here for this end. . . . Each drop of nectar rests on its gland just under the hairs with which the edges of the two adjacent petals are beset.


Das
entdeckte Geheimniſs
der
NATUR
im Bau und in der Befruchtung
der
Blumen
von
CHRISTIAN KONRAD SPRENGEL,
Mit 25 Kupfertafeln.
Berlin, 1793.
bei Friedrich Vieweg dem ælteru.

FIG 2.

As the flower is upright and is quite large, rain-drops must fall into it when it rains. But the drops cannot reach the nectar and mingle with it, because they are held back by the hairs, just as a drop of perspiration flowing over a man's forehead is held back by the eyebrows and eyelashes from running into the eyes. An insect, however, is not in the least hindered by these hairs from reaching the nectar. I now examined other flowers and found that many of them had something in their structure which seemed to answer the same purpose. The more I studied the subject, the more plainly I saw that those flowers which contain nectar are so constructed that while the insects can easily reach it, the rain cannot destroy it. I therefore concluded that the nectar was secreted for the sake of the insects, and that it was protected against the rain in order that they might enjoy it pure and uninjured.

"In the following summer I examined the Forget-me-not. I found that the flower had nectar and that this was fully protected against the rain. At the same time I was struck by the yellow ring which surrounds the throat of the corolla, and looks so beautiful against the sky-blue côlor of the petals. Can this also, I thought, have reference to the insects? Has Nature colored this ring to show them the way to the nectary? With this

hypothesis in my mind I examined other flowers, and found that most of them confirmed it. For I saw that those flowers which have variegated corollas always have the spots, figures, lines, or shadings of a particular color where the entrance to the nectary is to be found. . . .

"In the summer of 1789, when I was studying some species of Iris, I soon found that Linnaeus had been mistaken in the location of the stigma, as well as of the nectary, that the nectar was fully protected against the rain, and, lastly, that there was a specially colored portion which led the insects directly to the nectary. But I found, further, that this flower cannot possibly be fertilized except by insects, and those of a certain size only. . . . I then examined to see whether other flowers were so constructed that fertilization could only take place by means of insects. My study convinced me more and more that many, indeed, perhaps all, flowers which have nectar are fertilized by nectar-eating insects. . . .

"In the spring of 1790, I perceived that *Orchis Morio* had the complete structure of a flower with nectar, but possessed none. My first thought was that this observation must throw discredit on all my previous discoveries, or, at least, render them very doubtful. For if this flower has a nectar-guide (so I call the spot of a different color on the

corolla), and yet, nectar being absent, this is not intended as a pathfinder for the insect, it seemed to follow that these guides in the flowers which contain nectar had not this object at all, and that the whole was therefore a delusion. I must confess that this discovery was by no means agreeable to me. But this very thing spurred me on to study the flower more carefully and to observe it in the fields. I found out, finally, that these flowers are fertilized by certain flies which, deceived by its appearance,[1] expect to find nectar in the spur, and in creeping in draw the pollen masses out of their cells and bring them against the sticky stigma. . . .

"In the summer of the same year, I discovered in the *Epilobium angustifolium* (Fig. 3) something which I should never have thought of for myself, namely, that this perfect flower is fertilized by humblebees and hive bees, but that each individual is fertilized with another's pollen, the older flowers being fertilized with the pollen which the insects bring from the younger flowers. This discovery threw a great light over many of my earlier discoveries . . . because I had previously thought

[1] Darwin afterwards showed that the nectar in *Orchis Morio* was contained between the upper and lower tissues of the corolla, "On the Fertilization of Orchids by Insects," pp. 39–40. This opinion was subsequently confirmed by Müller, "Fertilization of Flowers," p. 537.

that all perfect flowers must be fertilized with their own pollen.

"When I, finally, last summer examined the common Wolf's Milk (*Euphorbia Cyparissias*) I

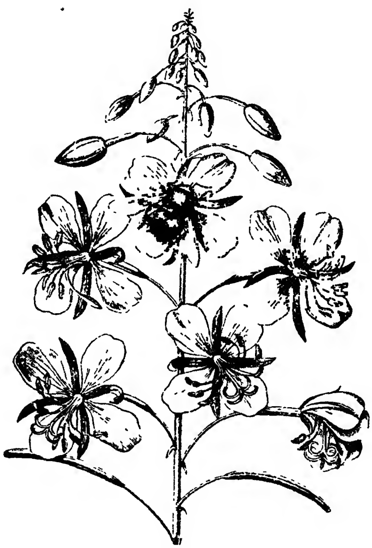


FIG. 3. EPILOBIUM ANGUSTIFOLIUM ("Pflanzenleben.")

found that this flower was so arranged as to be exactly the opposite of the last described; it is fertilized by insects, but so that the pollen of the older flowers is brought to the stigma of the younger ones.

"On these six discoveries, made in the course of five years I base my theory of the flower."

Sprengel's theory of flowers which contain nectar is, briefly, that these flowers are fertilized by insects which suck the nectar, and in so doing brush off the pollen and apply it to the stigma, and that the color, scent, and markings of such nectar-bearing flowers are for the purpose of attracting and guiding the insects. This view he proceeds to prove by observations on several hundred of his native flowers, observations which are full of interest and are related with a most charming simplicity.

He mentions five things possessed by flowers which contain nectar. The nectar glands, which secrete the sweet liquid; the nectar receptacle, which receives it; the nectar covering, which protects it from the rain; the nectar guides, color and scent, by which the insect finds its way to the honey, and, lastly, contrivances by which the insect is prevented from fertilizing the flower with its own pollen, such as the maturing of the style and stigma at different times, to which he gave the name of dichogamy.

Naturalists at the time of the appearance of this book were entirely occupied with systematic Botany, to which the work of Linnaeus had given a great impetus, and, later, with studying the anatomy of the plant. It was destined to be many

years before Sprengel's method of studying the plant as a living thing was to be pursued. The man who turned the attention of observers permanently in this direction was Charles Darwin.

Sprengel's work failed to hold the attention of scientific men, principally because he had not given any real reason for all the wonderful contrivances which he described. He did not see clearly enough to impress it on others that there was any advantage to the plant in these peculiar arrangements. Although he did understand that one plant was often crossed with pollen from another plant, he did not show any reason why this should be, if the necessary object could be attained in a simpler manner by fertilizing the plant with its own pollen. Therefore students thought his theories all his own fancy, and did not even take the trouble to look into his facts.

Several other observers, among them Andrew Knight (1799), took up this subject, and Knight went farther than Sprengel in affirming that cross-fertilization was desirable, but he offered no experimental proof, and the matter rested until Darwin, by a series of brilliant experiments, lasting eleven years, showed that the offspring of cross-fertilized plants were superior to those of self-fertilized parents. He thus supplied the reason

for cross-fertilization, and the essential truth of Sprengel's observations was very clear.

He was led to make his long series of experiments in the following way: In order to determine some point in reference to his work on the origin of species he raised two beds of the common Toadflax (*Linaria vulgaris*), one containing seedlings from self-fertilized, the other from cross-fertilized parents. To his surprise, the crossed plants were larger and stronger than the others. The same result took place in some experiments upon the Carnation. His interest and attention being thoroughly aroused he undertook a long series of experiments on the subject.

Before this, however, he had spent much time and thought on cross-fertilization. His first paper was on the flowers of the Kidney-bean, and was thus described in a letter to Dr. Gray, Sept. 5th, 1857: [1]

"Lately I was led to examine buds of Kidney-bean with the pollen shed, but I was led to believe that the pollen could hardly get on the stigma by wind or otherwise, except by bees visiting the flower and moving the wing petals; hence I

[1] "Life and Letters of Charles Darwin," edited by his son, Francis Darwin. New York. D. Appleton & Co. 1888. II., p. 435. A paper on "Papilionaceous Flowers" was published in the *Gard. Chron.*, 1858, p. 828, and another in 1861, p. 552.

included a small bunch of flowers in two bottles in every way treated the same; the flowers in one I daily momentarily just moved, as by a bee; these set three fine pods, the other *not one*. Of course this little experiment must be tried again, and this year in England it is too late, as the flowers seem now seldom to set. If bees are necessary to this flower's self-fertilization, bees must almost always cross them, as their dusted right-side of head and right legs constantly touch the stigma.

"I have, also, lately been re-observing daily *Lobelia fulgens*. This in my garden is never visited by insects, and never sets seeds unless pollen is put on the stigma (whereas the small blue Lobelia is visited by bees and does set seed). I mention this because there are such beautiful contrivances to prevent the stigma ever getting its own pollen, which seems only explicable on the doctrine of the advantage of crosses."

In 1861 Darwin occupied himself with orchids[1] and was astounded at the marvelous adaptations revealed by his study. These researches prove beyond any question that many flowers are furnished with the most wonderful mechanisms for the purpose of bringing about cross-fertilization by means of insects.

[1] "On the Various Contrivances by which Orchids are Fertilized by Insects." By Charles Darwin. D. Appleton & Co. New York. 1877.

His next book on the subject is the one previously mentioned as the result of the experiments of eleven years, "Cross and Self-Fertilization." [1] In this book he points out most clearly the advantage of cross-fertilization to the offspring. In a letter to Bentham, dated April 22, 1868, he says: "I am experimenting on a large scale on the difference in power of growth between plants raised from self-fertilized and crossed seeds, and it is no exaggeration to say that the difference in growth and vigor is sometimes truly wonderful. Lyell, Huxley, and Hooker have seen some of my plants and been astonished, and I should much like to show them to you. I always supposed until lately that no evil effects would be visible until after several generations of self-fertilization, but now I see that one generation sometimes suffices, and the existence of dimorphic plants and all the wonderful contrivances of orchids are quite intelligible to me." [2]

In 1867 he published an account of the plants which have different forms of flowers in the same species.[3] Part of the subject-matter of this book is treated in the chapters on Cleistogamous Flowers and Heterostyled Flowers.

[1] "Cross and Self-Fertilization of Plants." By Charles Darwin. D. Appleton & Co. New York.

[2] "Life and Letters of Charles Darwin." II. p. 465.

[3] "The Different Forms of Flowers on Plants of the same Species" By Charles Darwin. D. Appleton & Co. New York. 1877.

Since Darwin's time there has been an enormous mass of literature on the subject. The most important single work is Hermann Müller's "Fertilization of Flowers."[1] Müller studies the subject likewise from the side of the insect and its adaptation to the flower. He emphasizes a point on which Darwin laid insufficient stress, namely, that the point of primary importance to the plant is that it should set seed. Therefore many flowers are capable of self-fertilization, even though they may often be crossed, and we must not fall into the error of believing that self-fertilization is uncommon.

Neither must we state broadly that every color, form, and marking is of some definite use to the plant. These characters may be determined by the necessity of its structure, as, for example, if color is desirable for the sake of attracting insects, the organ must have a fleshy structure, as color cannot exist in dry and juiceless tissues.

[1] "The Fertilization of Flowers." By Professor Hermann Müller. Translated and edited by D'Arcy W. Thompson. London. Macmillan & Co. 1883. This book contains also a bibliography of the pamphlets and scattered papers on cross-fertilization up to 1883.

II.

FERTILIZATION OF TROPAEOLUM.[1]

THE flowers stand on upright stalks in a horizontal position, which is unusual, and are therefore irregular. This irregularity shows itself first in its means of protection against the rain. Both edges of the three lower petals are beset with a narrow fringe, where the border joins the claw. The raindrops which fall on the petals cannot run down the claws into the spur, but are caught in the niches made by this fringe, where we find them after a rain. As the raindrops fall on the outside of the two upper petals no such protection is needed, while it would also lessen the conspicuousness of the nectary.

The irregularity of the flower is shown further in the nectar guides. The corolla is yellow; the calyx is also yellow, and not, as usual, green, because it is very little covered by the corolla and can add to the showiness of the flower. All the five petals have a red spot at the base of the

[1] "Das Entdeckte Geheimniss der Natur," by Christian Conrad Sprengel. p. 214.

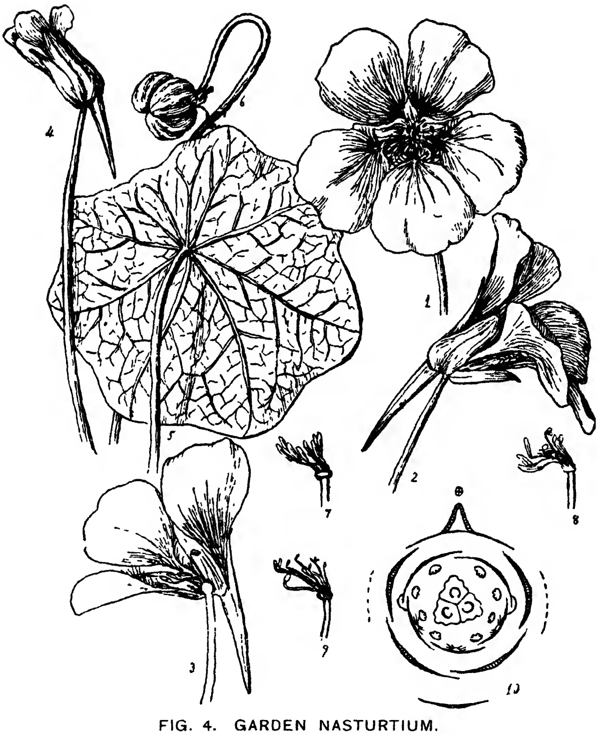


FIG. 4. GARDEN NASTURTIUM.

1, Front view of flower, 2 Side view of flower, 3, Vertical section; 4, flower-bud; 5, Leaf; 6, Fruit; 7, 8, 9, Stamens and style in successive stages; 10, Diagram (Eichler).

border. These spots form the outer nectar guides and show the insects that between them lies the path to the nectar. Where the petals are entirely red, it seems to be because the red spots, by superfluous nourishment, have spread over the entire surface.

The spots on the upper petals are darker, and are marked with brown lines, which unite at the end of the claw. Besides these petals, the three upper lobes of the calyx, but never the two lower, are also marked with brown lines. Finally, the upper but never the lower side of the spur is marked with brown lines, which run down to the nectar. All these make the inner nectar-guide, which leads the insect directly to the nectar. The upper petals must be marked differently from the lower ones because they are nearer to the nectary, and for the like reason the calyx is marked above and not below. An insect looking into the bottom of the flower sees the upper, never the lower side of the spur, and it would therefore be useless that the latter should be marked. If the upper petals had a nectar covering like the lower, an insect could not see past the fringe into the spur, and the inner nectar guide would become useless.

The nectar of the flower is intended for a large insect, and this must pay for its feast by fertilizing the flower, according to the following way. After

the flower has opened the essential organs are in the position of Fig. 4^7. The filaments are bent downward, the anthers have not opened, the style is very short, and the stigma has not expanded. Soon the seventh stamen begins to rise and to straighten, the anther opens, becomes round, and is overflowing with pollen (Fig. 4^3). The following day the second anther undergoes the same change. The seventh stamen, however, which has served its purpose bends again downward. This process goes on, so that the following stamens mature in the following order: 4, 8, 5, 3, 6, 1, and last about a week.[1] Finally, all the anthers are again declined and are withered. The above order is the most usual, but some flowers follow the following order: 2, 7, 5, 4, 1, 6, 3, 8. The style remains short and declined while the stamens discharge. As the anthers continue to mature, the style becomes longer and longer, and its position more upright, and the stigma begins to open. After all the stamens have matured and are bent aside, the style attains its full length, and stands in the same place where each stamen in turn has stood (Fig. 4^9).

In this manner it follows that a large insect must carry the pollen of the younger flowers to

[1] In our climate the time of discharging does not exceed three days. It is likely that in Germany the flower is more slow in its development.

the mature stigma of the older ones. In the young flowers the insect cannot reach the nectar without rubbing off the pollen from the discharging stamens upon the under side of its body. Nor can it reach the nectar in the older flowers without depositing some of this pollen on the stigma, which stands in exactly the same relation as did the stamens to the body of the insect. In order that this may be unavoidable the stigma stands quite free, and the withered anthers are bent aside. As the insect flies from flower to flower it cannot avoid fertilizing the older from the younger flowers.

It is probable that the flower is fertilized by bees, for Gleditsch says that it is visited by these insects. I, myself, have never seen a bee upon it. In the spur of the flower I found an ant. Small spiders were there, also, probably to hunt the little insects which ventured in. I found also the same dull and stupid insect which I have seen on other flowers. It showed by its behavior that it was not intended to aid in the fertilization, for it mistook the nectary covering for the nectary, stuck in its proboscis, and, as it had rained, found raindrops therein.

This flower has taught me that man may easily err in his judgment of the works of Nature if he ventures this judgment without observing her purposes. For before I had discovered the peculiar

manner in which the flower is fertilized I could not see the least trace of order or beauty in the arrangement of the essential organs, but all appeared to be confusion. I saw some filaments stretched straight upwards with mature anthers, others declined with unripe anthers, and still others bent more aside with withered anthers. As the filaments surround the base of the ovary regularly, I thought that they should have had a similar inclination and direction towards the style as their common axis, and that their anthers should mature at the same time. What, however, would have been the result of this fancied improvement? This, — that the flowers could only have offered their pollen to insects for a single day, while after the plan arranged by Nature the pollen lasts for a week. We shall not consider this time too long if we recollect that rainy days must be taken into account. For the anthers which mature then mature in vain, as the pollen is destroyed by the rain, and the insect also is hindered from visiting the flower. In the second place the insect could never rub off the pollen of the lower stamens, because the upper ones would prevent them from touching its body.

III.

THE PROTECTION OF POLLEN.[1]

THE pollen of many of those plants which grow wholly under water, as, for example, the *Zostera*, differs from the pollen of other flowering plants in a marked way. This *Zostera* may be better known to us as eel-grass, and is used for packing glass-ware and also for stuffing mattresses. As found growing in the water, it consists of brownish-green, ribbon-like filaments, resembling the common *Fucus* or brown sea-weed.

The anthers as they develop under water are closely packed with what resembles a tuft of threads. When, however, the anther bursts, we see that this tuft of threads is really the pollen, composed of slender cylindrical filaments and lacking the characteristic outer coat (the extine) of most pollen grains. The pollen is then carried to and fro by the water till it is brought in contact with the thread-like pistil, when impregnation

[1] Condensed extracts from "Pflanzenleben," translated by Miss A. M. Mitchell. Vol. II. p. 105.

takes place at once, since the usual formation of the pollen-tube has already been accomplished. . .

With the exception, however, of about fifty species which develop their pollen in a manner similar to the *Zostera*, the pollen of flowering plants is injured by long continuance or transportation under water. If the pollen grain is plunged into water or while remaining in the flower is wet by rain or dew, a striking change takes place. The pollen becomes distended, the cell-contents become turgid and the inner coat breaks the outer coat where it offers the least resistance. Often the protoplasmic contents escape from the cell-sac and the pollen grain is completely destroyed. This is quite different from the growth of the pollen-tube under the influence of the viscid secretion of the stigmatic surface. In the latter case, the change is gradual and a true growth takes place; in the former, the change is a sudden distension from the rapid absorption of water. It is therefore evident that some provision of nature is necessary to guard that most valuable product, the pollen, from the destructive action of the rain and dew.

In countries where the wet and dry seasons alternate, as in the plains of Venezuela and Brazil, where all the rain falls during the winter, the protection of the pollen is effected by the climate.

The European Globe-flower (*Trollius Europæus*), which is found in the northern marshes, has, completely covering the anthers, a series of spirally over-lapping calyx leaves, which the bee, in his quest for honey, easily pushes aside, but which the rain endeavors in vain to penetrate. The corolla of the *Corydalis*, the *Calceolaria*, the Toad-flax (*Linaria*) and the Snap-dragon (*Antirrhinum*) forms a closed hollow covering over the stamens in a manner somewhat similar to the Globe-flower.

Most flowers with a labiate corolla, also the *Pinguicula* (Butterwort) *Rhinanthus*, *Melampyrum* (Cow-wheat), *Euphrasia* (Eyebright) and the Violets, protect the pollen by means of a hollowed portion of the upper corolla lip. In the *Hydrangea quercifolia*, a native of Florida, we notice two kinds of flowers ; those in the centre of the cluster, which are inconspicuous, but perfect, and the spreading, showy flowers of the border, which, however, are neutral (Fig. 7[8]). These latter serve another purpose than the gratification of the sense of sight, for they are like an umbrella spread over the less beautiful, but more useful flowers, and shield them completely from the rain.

In the *Iris* we notice a striking modification of the pistil for the protection of the pollen. The three spreading stigmas resemble corolla leaves, and are slightly reflexed and two-toothed at the

apex. Under each stigma is an anther, sheltered beneath the concave surface from the entrance of a single drop of rain.

In the *Primulas, Phlox, Daphne,* and other flowers, having a salver-shaped corolla, the mouth of the corolla-tube is turned to the sky, so that it would seem to be unprotected from the rain. However, if we examine the flower carefully, we shall notice a slight constriction of the corolla just at the mouth of the tube and, immediately above the anthers, minute callosities, so that however fiercely the rain may beat upon the flower it cannot force its way into the corolla-tube and dampen the pollen.

Instead of the protection of the pollen by the various parts of the flower, the same effect may be brought about by a change of position either of the flower itself or of the sepals and petals. In such plants as the Crocus, Colchicum, Gentian, Pæony, or the common white Water-lily, we can easily see how soon the rain and dew would ruin the flowers if the cup-shaped corollas were left exposed. Accordingly in the day-time under the influence of the warm sunshine the flowers are wide open, but, at the falling of the dew at the approach of evening, the leaves fold together again and shut out the moisture. On damp, chilly days also the flowers do not open.

The petals of those flowers which close at night increase in size to correspond with the development of the anthers, so that at the end of the flower's life, the petals are sometimes twice as long as

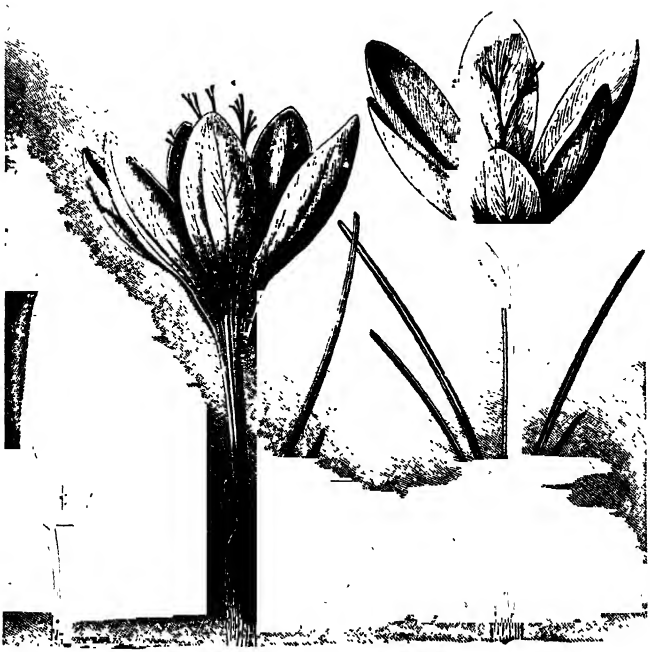


FIG. 6. CROCUS MULTIFIDUS. ("Pflanzenleben.")

when the flower first opened. In the winter Aconite (*Eranthis*) and other *Ranunculaceæ*, the pistil or pistils are surrounded by several rows of stamens, of which the outer rows develop first. The pollen

of the outer rows is accordingly shed while the filaments are quite short. Then the filaments lengthen and another row of anthers mature and shed their pollen, but by this time the petals have also in-

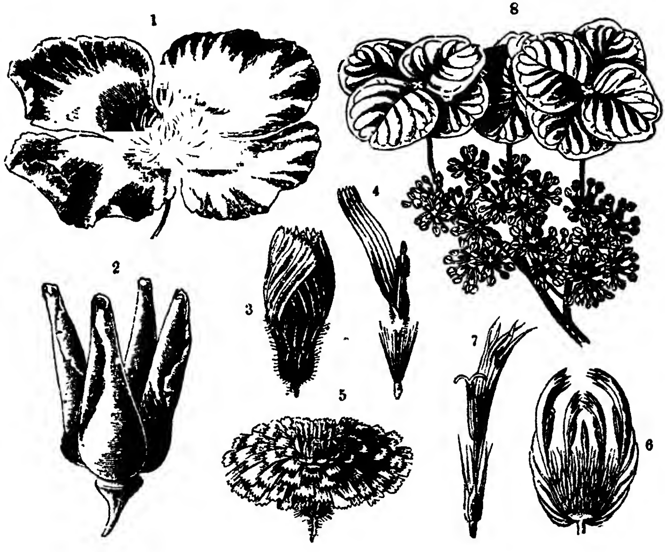


FIG. 7.

1. Eschscholtzia Californica, open. 2. The same, closed. 3. Hieracium Pilosella, closed. 4. Single flower of the same. 5. The same, open. 6 Section of Catananche Coerulea. 7. Single flower of same. 8. Hydrangea quercifolia. ("Pflanzenleben.")

creased in size. So the growth goes on until all the stamens have shed their pollen. In the *Eranthis* there has been observed a growth of the petals from 11 to 22 mm. and in the Hepatica from 6 to 13 mm.

A slightly different method of protecting the pollen by the closing of the corolla is observed in the *Eschscholtzia Californica* (Fig. 7[1,2]). By day the golden leaves are wide open and the pollen falls from the anthers in a mealy mass upon the base of the four saucer-shaped petals, forming little mounds about ·1 mm. in height. When evening comes, the anthers, which have lost their pollen, are not protected, but each petal is rolled about the mass of pollen at its base somewhat after the manner of a paper horn.

The closing at night of many Compositae having heads composed wholly of ligulate flowers, as the Dandelion and Chicory, is very familiar. We remember, too, how in these flowers the anthers are united in a tube about the pistil. The pollen falls from the anthers on the inner side of the tube and collects around the base of the pistil, whence it is carried away by the bees. To protect any pollen that may be left in the flower at night the separate flowers fold together to form one protective covering, and only open again in the warm sunshine.

. . . .

The pollen of the Plane tree and many conifers, notably the Juniper and Yew, is protected by the scale-like filaments on which the anthers are borne. These scales are arranged similarly to the scales

of a fir cone, and, like the fir cone, are sensitive to moisture, *closing tightly together in damp weather* and separating in dry weather. When the scales are open the dissemination of the pollen can easily take place ; but, in damp weather and at night, it is securely packed away beneath a protective covering.

The stalks of many pendulous flowers have the power of movement to shelter the pollen. Commonly this curving of the peduncle takes place just before the opening of the flower and continues as long as the pollen remains in need of protection. In many *Campanulas*, *Scrophularias* and *Primulas*, several *Ranunculaceæ*, many of the Lily family, we see this power of movement. The buds are erect upon their stems, so that the mouth of the flower is turned to the sky. Just before the flower opens, the peduncle curves so that the mouth of the flower is turned more or less to the ground. In most cases when the time of blooming is over and the pollen has been shed, the flower stalk straightens again so that the fruit is erect.

In flowers which grow in dense clusters, instead of a bending of each flower a movement of the whole cluster frequently takes place, as in the Cherry, Barberry and *Scabious* (Fig. $8^{2,3}$). In the case of the closely packed catkins of many trees, as the Walnut, Birch, Hazel, Alder and Poplar,

the axis lengthens before the flowers open, and becomes pendulous so that the small perigonal leaves or bracts form a roof over the stamens. As the

FIG 8 HERB-ROBERT SCABIOUS

1. Herb-Robert in sunny weather. 2 Sweet Scabious in fine weather. 3 The same in rainy weather 4 Herb-Robert during rain. ("Pflanzenleben.")

anthers open the pollen falls into a depression found on the upper side of each flower. There it remains until a breath of wind comes and bears it away to the pistil of another flower, so that each

flower not only protects its own pollen, but is a receptacle for the pollen of the flower immediately above it.

The movements of the peduncle in some flowers to mark the changes of day and night, and of good and bad weather, are most curious and interesting. Such flowers are found in very distinct families, but have the common characteristics of long, slender peduncles and spreading corollas. On bright, sunny days, the flowers are turned to the sun and swarm with insects, but at night, or in rainy weather, when the insects will not visit them, the flowers are turned towards the earth.

We shall find many of our common flowers which are not protected in any of the ways we have noticed. From the time the flower first opens until it fades the anthers are exposed to all the changes of the weather, and in such flowers as the *Plantain* and *Globularia*, with their anthers exposed on long slender filaments, it would seem as if the pollen must be ruined. Close examination shows us that the pollen is not unprotected, since in dry weather the anthers open and expose the pollen, but in damp weather they close together and shut up the pollen as in a close box. . . .

These various flower movements have often another purpose besides the protection of the pollen.

In many cases they serve also to protect the nectar which would otherwise become mixed with water and ruined. By the contraction of the corolla tube and closing of the corolla many unwelcome visitors are excluded who would rob the flower of its nectar and pollen and give it nothing in return.

IV.

THE GROWTH OF EARLY SPRING FLOWERS.

When the first growing days of spring come, and after the rains the April sun bursts out as warm as June, we stand amazed at the sudden transformation that takes place in the landscape. The leaves seem not to grow but actually to jump out. In a few days the trees which had been covered by a faint, misty haze of green, spring into full leaf, and only the Oaks and Beeches remind us that winter is not far behind us. The flowers appear as suddenly, and Hepaticas, Bloodroot and Violets soon gladden our eyes.

How is this sudden growth possible? If the trees and herbs were obliged to wait until they had slowly made the food required for this transformation, a few warm days and soaking showers would have little effect in bringing it about. All through the previous summer the surplus food-substances formed in the leaves, the starch-factories of the plant, have been carried to safe places in stem and root and laid up for future use.

Through the winter this store of food has lain safely, waiting for its appointed time, and as soon as the rain and sun have started the buds, the starch absorbs moisture and is turned into a sort of sugary sap, which takes up more room than the dry starch and forces its way into every twig of the tree. The growing buds absorb this sweet sap and unfold with marvellous rapidity.

If we examine any very early herb we shall find somewhere at the base a storehouse of food. Let us look, for instance, at one of our commonest weeds, the Dandelion. If we pull up a plant we shall see a long, tapering, fleshy root (Fig. 9) which is full of food, put there during the previous summer. In the spring the new leaves do not have to make food before other leaves and flowers can develop, but they can draw on the prepared store. The Dandelion uses its root for its storehouse, so do the Carrot and the Beet, the Radish and the Turnip, which are used by us for food. Other plants store the food in their stems. Many of our spring plants have large, creeping, underground stems, which throw up new shoots every year. The Solomon's Seal takes its name from the seal-like scar at each place where a shoot has grown and withered in former years, and the Bloodroot is named from the red juice which fills its underground stem and

stains our fingers, making us look guilty of some crime. But it is not a crime to pick all the Bloodroot that we want. Safe beneath the ground are the tiny forming buds that will throw up the blos-

FIG. 9. DANDELION

soms and leaves next year and we cannot hurt them. But the wild flowers which have no creeping underground stems provided with buds, depend on their seeds for future descendants, and we must

not pick them all. The Violet and the Anemone also have a storehouse in their underground stems, and the stem of the Violet is covered with fleshy teeth. The teeth are the remains of former leaves, while the upper part above the ground has withered away. In the Anemone the underground sheaths are modified leaves, and from their axils spring branches to continue the growth for the following year.

In all our bulbous plants, Snowdrops, Crocuses, Tulips, Dog-tooth Violets (*Erythronium*), and Trilliums the food is stored in the base of the stem or in the bases of the leaves. The green leaves of a Tulip die down to the ground after flowering-time is over, but it has first deposited its provision for the following spring in the underground part of the leaves, which become fleshy and gorged with nourishment. We call these storehouses bulbs, and the name is given in common speech to the underground part of the Crocus also, where the food instead of being stored in the bases of the leaves is collected in the base of the stem.

Any organ of the plant may thus be utilized as a storehouse of food, and we can name many examples of plants which so use their roots, their stems and their leaves. In our trees the food is stored principally in the branches where it is close at hand to supply plenty of sap to every little

bud as soon as it begins to swell in the spring-time.

It is not merely the cold of winter that prevents

FIG. 10. ANEMONE NEMOROSA ("Pflanzenleben.")

growth. Most plants have a resting or dormant period, which, in our climate, coincides with the winter-time. We can prove that the cessation of

growth is not wholly caused by the cold, by bringing branches into the house soon after the fall of the leaves. They will not develop, however much we may feed them with fresh water and warm them by the fire. But in January, or certainly in February, they will put forth their leaves even under less favorable circumstances. The same is the case with tubers and bulbs.

"The leaf-shoot and flowers contained in the bulb of the Crown Imperial (*Fritillaria imperialis*)," says Sachs, illustrating this point,[1] "commence to grow vigorously in the spring-time with us, even at the beginning or middle of March, when the soil in which the bulb has passed the winter possesses a temperature of 6-10*C* (44.7–52.2*F*) the leaf-shoots protrude forcibly from the cold earth to grow vigorously in the but slightly warmer air. There would be but little to surprise us in this if we did not at the same time notice the fact that a new leaf-shoot is already formed in embryo in the subterranean bud in April and May: this shoot, however, does not grow to any extent in the warm soil during the summer and autumn. On the contrary, this favorable period of vegetation passes by, until at the end of

[1] "Lectures on the Physiology of Plants," by Julius von Sachs, translated by H. Marshall Ward. Oxford. Clarendon Press, 1887, p. 350.

the winter an inconsiderable rise of temperature above the freezing point suffices to induce vigorous growth, and, as is well known, the same is the case with most bulbous and tuberous plants, many of which, as the Meadow Saffron, possess two active periods, the flowers developing in the late autumn and the foliage-leaves belonging to them only in the next spring. The best known examples, however, are afforded by the common potato and the kitchen onion. I have many times attempted to induce the tubers and bulbs ripened in the autumn to put forth their germinal shoots during November, December and January, by laying them in warm, moist, loose soil, but in the case of the potato, as well as in that of the kitchen onion, no trace of germination appeared. If, on the other hand, the attempt is repeated in February, or, still better, in March, the germinal buds begin to grow vigorously even in a few days. At this time of the year, indeed, it does not even require a favorably high temperature and an external supply of water ; the shoots begin to develop at much lower temperatures, and this, even when the potatoes and bulbs do not receive the addition of water from without. Not only so, they will put forth germinal shoots when suspended in dry air and shriveled up by the loss of water. It is evident that some internal change must have taken place in the tubers and

bulbs during the winter months when it is impossible to bring them into activity from their state of rest, since no such change is perceptible externally, and the behavior described appears inexplicable otherwise.

"The behavior of the Water-Nut, the fruit of *Trapa natans*, is perhaps still more striking. If at the end of August, or in September, when they are ripe, one of these is placed in a glass full of water, no germination occurs either during the autumn or winter, even in a chamber where the water is constantly at 15-20 *C* (63.8–74.4 *F*), but in March or April germination begins although the water is only at a temperature of 8-10 *C* (49–53 *F*). The most striking examples of periodic rest and activity are probably afforded, however, by the majority of woody plants, especially those which produce winter buds clothed with scales, such as the Horsechestnut, ordinary fruit trees, and species of *Pinus* and *Abies*. As soon as this year's foliage and flower-shoots have become unfolded in the spring from the winter buds of the previous year, the winter buds of next year are formed in embryo. The future shoots or even flowers develop slowly within the bud-envelope, but remain in an embryonic condition, and it is impossible by any means to cause these embryonic shoots to develop in the autumn or the beginning of winter. On the other hand,

they develop in January, or better in February, if branches furnished with buds are cut off and allowed to stand in water in an ordinary warm dwelling-room — that is at a temperature of about 15–20C (63.8–74.4F). The winter-buds of trees thus behave just like subterranean bulbs and tubers."

The provision for rapid growth in our spring flowers is not confined to the storing of food, but in all of our earliest flowering plants the flower-buds themselves are developed in the previous summer and protected in various ways during the winter. We have already studied this in our trees. We have seen how the Horsechestnut and Magnolia, the Elm and Maple, begin to form their flower-buds in June, and develop through the summer, until winter sees them snugly wrapped in fur-lined coverings or covered with resin to protect them from the changes of the atmosphere.

Not only in the trees, but also in our early perennial herbs, the flower-buds are formed in the previous season. If in fall or winter you see the leaves of the Hepatica and wish to satisfy yourself on this point, dig down to the underground stem and you will find the new leaves and flower-buds, already perfectly formed, waiting the proper time to appear. The same is true of the Violet, Bloodroot, wild Strawberry, Indian Turnip, Ladies' Slip-

per, Trillium, Spring Beauty, *Uvularia* and many more.

Some of our spring flowers have scaly buds which are not subterranean, as the Trailing Arbutus, where the buds are protected only with thin, brown scales, and the Prince's Pine and Pyrola.

In a paper on this subject August Foerste says :[1]

"All of these possess the same peculiarity of starting the formation of their flower-buds during the summer of the previous year, and often attaining a considerable development before the retarding influence of winter becomes effective. No doubt the warmer, sunny days of winter admit still further growth, so that when spring has actually come the increased warmth causes these flower-buds to complete their development rapidly and to assume the tinted garb in which we are more accustomed to recognize them. The earlier blossoming plants, such as the Bloodroot, Twin-leaf, Skunk-Cabbage and Trillium, usually show their flower-buds in the fall in a more advanced stage of development than those which flower later. The earlier flowering plants, also, as a rule have shorter stems and possess less foliage than those which blossom later. Perennial plants which do not develop flowers until late spring or during the summer, of course, also possess scaly winter

[1] "Torrey Bulletin." April, 1891. p. 101.

buds, but these buds only contain the earlier developing leaves; the later leaves and the flowers are not formed until the scaly bud has burst and the growth of the year has well begun."

The fact of the flowers being ready to develop under favorable circumstances explains why fall flowers of these spring plants are often found. In particularly warm seasons the flowers may be prematurely developed. We often see the Japan Quince (*Cydonia Japonica*) blossoming in the late fall, and Hepaticas and Strawberry blossoms are frequently found in December.

V.

CLEISTOGAMOUS FLOWERS

THE common Violet (*Viola cucullata*) has two kinds of flowers (Fig. 11). The familiar ones are well adapted to cross-fertilization and do not set seed without the aid of insects. Besides these irregular, showy flowers, there are small, inconspicuous flowers on erect pedicels near the base of the plant, which look like little green buds, but never open.

These flowers are larger than the similar flowers in any other species of Violet and are very easy to study. They are about a third of an inch in length (Fig. 11[a]). The calyx is composed of five sepals, which resemble the sepals in the ordinary flowers but are less auricled at the base. They never open until the growth of the fruit forces them apart. The corolla is often entirely absent, but sometimes one or two rudiments of petals can be found. There are generally two stamens, but sometimes we can find rudiments of others. The stamens have flat, brown filaments to which the two anther lobes are attached. The pollen-grains have very

thin, transparent coats and, without leaving the anther, throw out the pollen-tubes, which grow towards the stigma and make their way down the style to the ovary. The pistil has a hooked style

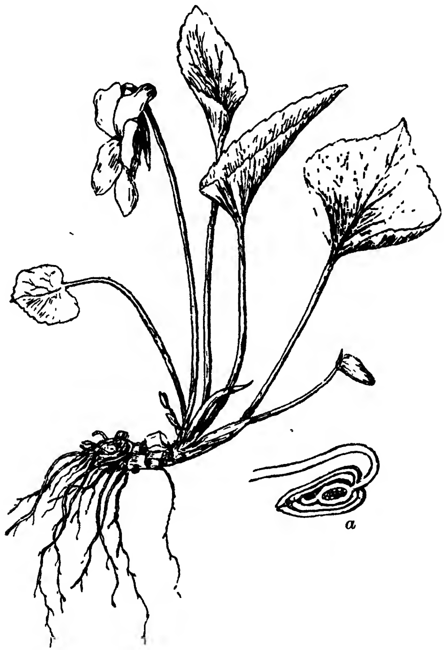


FIG. 11. VIOLA CUCULLATA.
a. Cleistogamous Flower.

which ends in a flat, stigmatic surface, with a cavity in the centre. This is covered by the anthers, so that the pollen-tubes do not have far to travel before entering the stigma. The whole

plan of the flower, therefore, is for self-fertilization, and, as insects cannot enter, color and scent have become unnecessary and are not developed.

These small closed flowers are called *cleistogamous flowers*.[1] The first exact researches upon the subject were made in 1733 by an author named Dillenius. He observed that a plant, afterwards named *Ruellia clandestina* by Linnaeus, bore first very small flowers with closed corollas, and, in the second year, large flowers about two inches long. The small flowers contained stamens and pistils, and produced fertile seeds, as well as the large flowers of the second year. He also described a species of Violet (*Viola mirabilis*) and stated that the spring flowers with showy corolla and stamens only rarely produced fruit, but that the closed flowers at the base of the stem, blooming later in the season, habitually lacked petals, but bore good fruit.

Some of these closed flowers seemed to be destitute of stamens, and were used as an argument to prove that the presence of stamens was not necessary to the production of seed. Linnaeus had asserted that there were sexes in flowers and that both stamens and pistils were essential to produce

[1] This name was given by Kuhn in 1867. The form used by Darwin was "cleistogamic," but Dr. Gray prefers "cleistogamous," for philological reasons.

seed, and he discovered the stamens in several of the cleistogamous flowers. He does not seem, however, to have found them in every case, though it has since been shown that they are always present.

Other flowers of this kind were discovered from time to time.

Hugo von Mohl summed up the history of the subject in 1863, and gave descriptions of all the known cases, together with new observations of his own.[1] In 1877 Darwin reviewed these observations, adding many more.[2] He gives a list of fifty-five genera in which these flowers are present. They are more common in the *Leguminosae* than in any other family. The plants best known to us which possess them are some of the Violets, some species of Oxalis and Polygala, the common Touch-me-not (*Impatiens fulva*) and some grasses.

Darwin thinks that these small closed flowers have been produced from the perfect ones by the arrest of development at an early stage of the flower-bud. He points out in support of this view the trace of a spur in the closed flower of Impatiens, the uniting of the stamens of a leguminous

[1] "Botanische Zeitung," 1863, p. 309. Hugo von Mohl. Dimorphische Blumen.

[2] "Different Forms of Flowers on Plants of the Same Species," by Charles Darwin. New York. D. Appleton & Co. Broadway, 1877, p. 310.

plant, *Ononis*, into a tube, and the fact that the lower rudimentary petal when present in the Violet is larger than the others. But this arrest of development cannot be the only cause of their structure, because they are adapted specially for self-fertilization. In the Violet the pistil is hooked to bring the stigma close to the stamens (Fig. 11[a]). In all of these flowers the pollen-grains have thin coats and the pollen-tubes begin to grow while still in the anther. Besides, in some cases it has been shown that the flower-buds differ as soon as they begin to form.[1]

The characteristics of the cleistogamous flowers may be summed up as follows: — They are much smaller than the conspicuous flowers on the same plant and never open, so that they resemble buds. Their petals are reduced in size and are sometimes altogether absent. The stamens are generally reduced in number and contain very few pollen-grains, and these grains send out their tubes while still in the anther. The pistil is smaller than the ordinary flowers, and the stigma is very little developed. The flowers do not secrete nectar or give out odor and are not visited by insects. They are thus self-fertilized, yet they produce much seed, often more than the conspicuous flowers. Very often the

[1] See the Journal of the Linnaean Society. Botany. Vol. xvii, 1880, p. 269. "Notes on Cleistogamic Flowers," by A.W. Bennett.

capsules bury themselves in the ground, as in the Wood-Sorrel; or are produced underground, as in the Polygala.

With regard to the sending out of the pollen-tubes while the grains are still within the anther, Darwin says:[1] "It is a wonderful sight to behold the tubes directing themselves in a straight line to the stigma, when this is at some little distance from the anthers. As soon as they reach the stigma or the open passage leading into the ovary, no doubt they penetrate it, guided by the same means, whatever these may be, as in the case of ordinary flowers. I thought that they might be guided by the avoidance of light; some pollen-grains of a Willow were therefore immersed in a weak solution of honey, and the vessel was placed so that the light entered only in one direction, laterally or from below or from above, but the long tubes were in each case protruded in every possible direction." It is not at all understood what the influence is that makes the pollen-tubes grow straight towards the stigma.

Some writers have argued that the existence of these flowers proves that cross-fertilization is not really an advantage to the offspring of a plant, because they are especially adapted for self-fertilization. But a little consideration will show that

[1] "Forms of Flowers," p. 337.

they really prove that cross-fertilization is generally desirable. Although Nature often appears to be wasteful, it is a rule that useless structures are dispensed with. Now these closed flowers are very economical to the plant. As the pollen is not exposed to the rain and insects there is no waste and less pollen being needed, less is produced. In some of the closed flowers of the Violet one hundred pollen-grains answer the purpose of the flower, while all irregular flowers crossed by insects have several thousand pollen-grains; and in the case of some flowers, as the Pæony, for instance, the number reaches several millions. Besides this, there is the cost of a corolla with its nectar and scent. If such economy were possible as a rule, nature would never have expended so much trouble in producing showy flowers and abundant pollen, and we may safely reason that they are necessary to the purpose of the flower and that the cross-fertilization they bring about is essential.

Darwin believes that cleistogamous flowers were developed partly because the conditions of climate prevented the forming of sufficient seed by the showy flowers, and partly to secure the economy of material which results. The perfect flowers are still occasionally cross-fertilized, and this secures the advantage of strengthening the offspring.

VI.

HETEROSTYLED FLOWERS.

If we study carefully the little Houstonia in our visits to the spring meadows, we shall discover that the plants grow in patches, which differ in aspect. In one patch the flowers are smaller than in the other, and the corollas do not spread so widely. We are apt to skip these groups of plants, and choose our bouquets from the more showy patches. When we examine the flowers more closely, we see that the smaller blossoms show four stamens in the throat of the corolla, while in the larger flowers the two stigmas only are visible.[1] Cutting the flowers open, we find the style of the first flower half way down the tube of the corolla, while in the other the stamens occupy a corresponding position (Fig. 12).

This difference in the length of stamens and style, so that each style corresponds with a certain length of stamens, is characteristic of other flowers also. It may be seen in Primroses and Flax, in

[1] The correspondence is not perfect in the Houstonia, the longer stamens being somewhat shorter than the long style.

the Partridge-berry, the Bouvardia, and many other plants belonging to the Madder family (*Rubiaceæ*), of which the Houstonia also is a member.

Sprengel knew of the existence of such flowers.

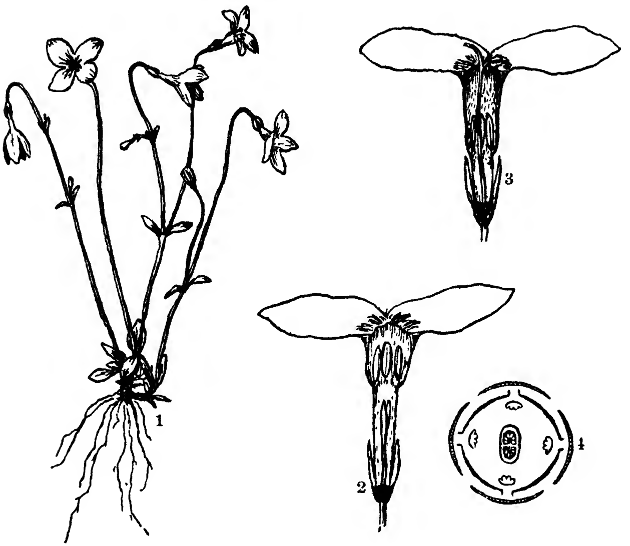


FIG. 12. HOUSTONIA CÆRULEA.
1. Whole plant (reduced) 2. Long-styled flower 3. Short-styled flower (magnified) 4. Diagram.

He says, in speaking of *Hottonia palustris*,[1] a plant belonging to the Primrose family, "Some of the plants have flowers with stamens half way down the corolla tube and the style rising above it, and

[1] "Das Entdeckte Geheimniss der Natur," p. 103,

other plants bear flowers with a short style and stamens longer than the corolla. Although I am not able to show the purpose of this arrangement, I do not believe it to be a matter of chance."

In 1877 Charles Darwin published a book entitled "Different Forms of Flowers on Plants of the Same Species." In this book he describes and explains such flowers as the Houstonia, which he names dimorphic (of two forms), though he afterwards adopted the name given by Hildebrand of heterostyled. He describes also plants with flowers of three lengths of style and stamens (trimorphic), and plants with rudimentary closed flowers (cleistogamic), as well as the conspicuous ones.

His first observations were upon the Primrose, one of the commonest of English flowers, known as Cowslip, and he thus narrates his observations in the beginning of his book :—

"It has long been known to botanists that the common Cowslip (*Primula veris, var. officinalis, Lin.*) exists under two forms, about equally numerous, which obviously differ from each other in the length of their pistils and stamens.[1] This difference has hitherto been looked at as a case of mere variability, but this view, as we shall presently see,

[1] This fact, according to Von Mohl (*Bot. Zeitung*, 1863, p. 326), was first observed by Persoon in the year 1794.

is far from the true one. Florists who cultivate the Polyanthus and Auricula have long been aware of the two kinds of flowers, and they call the plants which display the globular stigma at the mouth of the corolla 'pin-headed' or 'pin-eyed,' and those which display the anthers 'thrum-eyed.' I will designate the two forms as long-styled and short-styled (Fig. 13).

"The pistil in the long-styled form is almost ex-

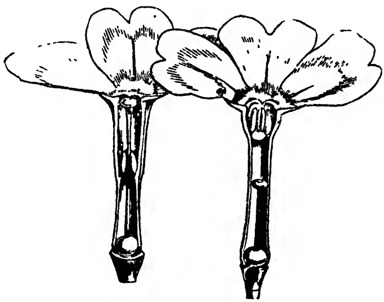


FIG 13. (Darwin.)

actly twice as long as that of the short-styled. The stigma stands in the mouth of the corolla, or projects just above it, and is thus externally visible. It stands high above the anthers, which are situated half way down the tube and cannot be easily seen. In the short-styled form the anthers are attached near the mouth of the tube, and therefore stand above the stigma, which is seated in about

the middle of the tubular corolla. The corolla itself is of a different shape in the two forms, the throat, or expanded portion above the attachment of the anthers, being much longer in the long-styled than in the short-styled form. Village children notice this difference, as they can best make necklaces by threading and slipping the corollas of the long-styled flowers into one another. But there are much more important differences. The stigma in the long-styled form is globular; in the short-styled it is depressed on the summit, so that the longitudinal axis of the former is sometimes nearly double that of the latter. Although somewhat variable in shape, one difference is persistent, namely, in roughness: in some specimens carefully compared, the papillæ which render the stigma rough were in the long-styled form from twice to thrice as long as in the short-styled. The anthers do not differ in size in the two forms, which I mention because this is the case with some heterostyled plants. The most remarkable difference is in the pollen-grains. I measured with the micrometer many specimens, both dry and wet, taken from plants growing in different situations, and always found a palpable difference. The grains distended with water from the short-styled flowers were about .038 mm. ($\frac{10-11}{7000}$ of an inch) in diameter, whilst those from the long-styled were

about .0254 mm. ($\frac{7}{7000}$ of an inch), which is in the ratio of 100 to 67. The pollen-grains, therefore, from the longer stamens of the short-styled form are plainly larger than those from the shorter stamens of the long-styled. When examined dry, the smaller grains are seen under a low power to be more transparent than the larger grains, and apparently in a greater degree than can be accounted for by their less diameter. There is also a difference in shape, the grains from the short-styled plants being nearly spherical; those from the long-styled being oblong with the angles rounded; this difference disappears when the grains are distended with water. The long-styled plants generally tend to flower a little before the short-styled; for instance, I had twelve plants of each form growing in separate pots and treated in every respect alike, and at the time when only a single short-styled plant was in flower, seven of the long-styled had expanded their flowers.

"We shall, also, presently see that the short-styled plants produce more seed than the long-styled. It is remarkable, according to Professor Oliver, that the ovules in the unexpanded and unimpregnated flowers of the latter are considerably larger than those of the short-styled flowers; and this, I suppose, is connected with the long-styled flowers producing fewer seeds, so that the

ovules have more space and nourishment for rapid development.

"To sum up the differences: The long-styled plants have a much longer pistil, with a globular and much rougher stigma, standing high above the anthers. The stamens are short, the grains of pollen smaller and oblong in shape. The upper half of the tube of the corolla is more expanded. The number of seeds produced is smaller and the ovules larger. The plants tend to flower first.

"The short-styled plants have a short pistil, half the length of the tube of the corolla, with a smooth, depressed stigma, standing beneath the anthers. The stamens are long, the grains of pollen are spherical and larger. The tube of the corolla is of uniform diameter except close to the upper end. The number of seeds produced is larger.

"I have examined a large number of flowers, and, though the shape of the stigma and the length of the pistil both vary, especially in the short-styled form, I have never met with any transitional states between the two forms in plants growing in a state of nature. There is never the slightest doubt under which form a plant ought to be classed. The two kinds of flowers are never found on the same individual plant."

Then follows long and careful descriptions of his experiments in crossing these two kinds of Cow-

slips. The results of his investigations may be summed up as follows: Both the long-styled and short-styled plants produce seeds when visited by insects, but are not self-fertile when insects are excluded. They set seed when fertilized by pollen from a similar flower, but are not fully fertile except when the pistil is fertilized from stamens of a corresponding length. This preference of the stigma for pollen of a different form than that produced by its own flower is so strong that the foreign pollen placed on a stigma a day after it has been dusted with its own pollen neutralizes the effect and fertilizes the flower. Darwin suspected that this would be the case and tried experiments to prove it. He says:[1] "To test this belief, I placed on several stigmas of a long-styled Cowslip plenty of pollen from the same plant, and after twenty-four hours added some from a short-styled, dark red Polyanthus, which is a variety of the Cowslip. From the flowers thus treated thirty seedlings were raised, and all these, without exception, bore reddish flowers; so that the effect of the pollen from the same form, though placed on the stigma twenty-four hours previously, was quite destroyed by that of pollen from a plant belonging to the other form."

[1] "Forms of Flowers," p. 31.

Many flowers are not at all self-fertile, but as soon as they are dusted by the pollen of a flower from another plant they will set seed; and in other flowers, as we have just seen, the ovary is fertilized from the pollen of the same plant, but more slowly than with foreign pollen. This arrangement, of course, is to aid cross-fertilization, and for the first class the visits of insects are necessary for the continuance of the species.

A minor result of Darwin's experiments was to show that the short-styled plants were the most fertile. This was a surprise to him, for in beginning his experiments he had supposed that the plant with long style and rough stigmas was the fertile form, and the other with long stamens was intended merely to produce the fertilizing pollen.

Darwin made the still more remarkable discovery that some plants possess three lengths of style and stamens, each form of style being only fully fertile when fertilized from stamens of a corresponding length. He thus describes this discovery in a letter to Dr. Gray.[1]

DOWN, Aug. 9, 1862.

MY DEAR GRAY, — It is late at night, and I am going to write briefly, and of course to beg a favor.

The Mitchella very good, but pollen apparently equal-sized. I have just examined Hottonia; grand difference

[1] "Life and Letters of Charles Darwin." II. p. 475.

in pollen. *Echium vulgare,* a humbug, merely a case like Thymus. But I am almost stark, staring mad over Lythrum; if I can prove what I fully believe, it is a grand case of TRIMORPHISM, with three different pollens and three stigmas. I have castrated and fertilized above ninety flowers, trying all the eighteen distinct crosses which are possible within the limits of this one species! I cannot explain, but I feel sure you would think it a grand case. I have been writing to botanists to see if I can possibly get *Lythrum hyssopifolia,* and it has just flashed on me that you might have Lythrum in North America, and I have looked to your Manual. For the love of heaven have a look at some of your species, and if you can get me seed, do! I want much to try species with few stamens, if they are dimorphic. *Nesæa verticillata* I should expect to be trimorphic. Seed! seed! seed! I should rather like seed of Mitchella. But, oh, Lythrum!

Your utterly mad friend,

C. DARWIN.

The accompanying diagrams (Fig. 14) show the three sets of organs in *Lythrum Salicaria,* a common North American plant. Each set of stamens corresponds in length with one of the pistils, and the flower is only fully fertile, as Darwin proved by a series of experiments lasting several years, when fertilized by stamens of the corresponding length. "When bees suck the flowers, the anthers of the longest stamens, bear-

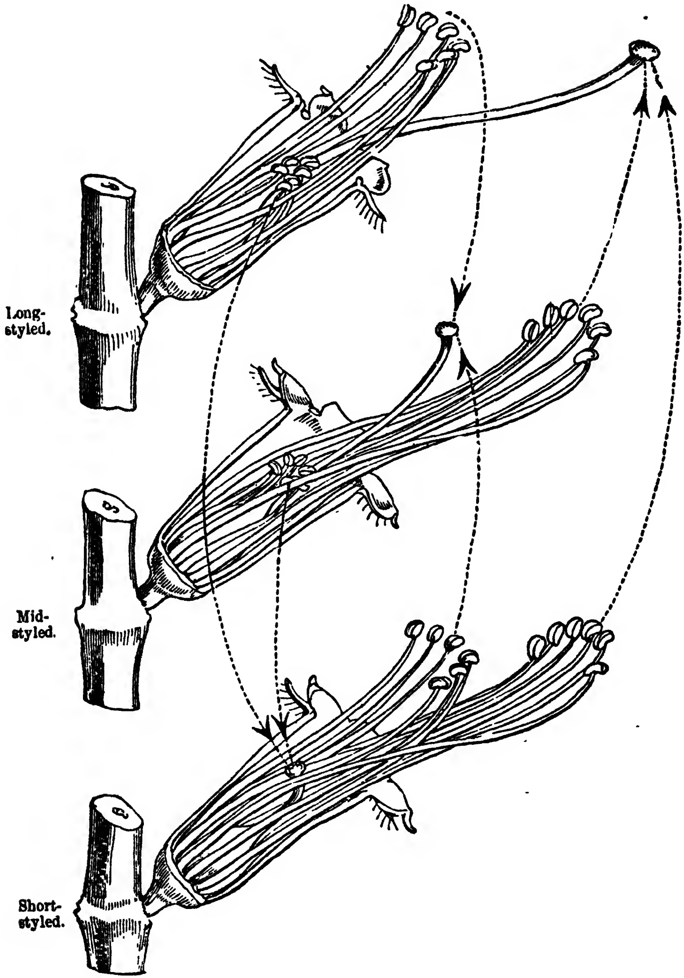


FIG. 14. ESSENTIAL ORGANS OF LYTHRUM SALICARIA.

ing the green pollen,[1] are rubbed against the abdomen and inner sides of the hind legs, as is likewise the stigma of the long-styled form. The anthers of the mid-length stamens and the stigma of the mid-styled form are rubbed against the under side of the thorax and between the front pair of legs. And, lastly, the anthers of the shortest stamens and the stigma of the short-styled form are rubbed against the proboscis and chin; for the bees in sucking the flowers insert only the front part of their heads into the flower.[2] . . . It follows that insects will generally carry the pollen of each form from the stamens to the pistil of the corresponding length. . . .

It is only pollen from the longest stamens that can fully fertilize the longest pistil; only that from the mid-length stamens, the mid-length pistil; and only that from the shortest stamens the shortest pistil. And now we can comprehend the meaning of the almost exact correspondence in length between the pistil in each form and a set of six stamens in two of the other forms; for the stigma of each form is thus rubbed against that part of the insect's body which becomes charged with the proper pollen."[3]

[1] The longest stamens have pink filaments and green pollen, the other stamens have uncolored filaments and yellow pollen.

[2] "Forms of Flowers," p. 147.

[3] "Forms of Flowers," p. 159.

Other trimorphous plants beside the various species of *Lythrum* are the *Oxalis*, of which we have several familiar species; as the Wood-Sorrel, (*O. Acetosella*), and the common little weed, Ladies' Sorrel (*O. corniculata var. stricta*). The blue Pickerel-weed (*Pontederia*) has also three kinds of flowers with three sets of stamens.

VII.

THE DISSEMINATION OF POLLEN BY THE WIND.[1]

In nearly all flowering plants it is necessary for the maturing of the seed that the pollen be carried from the stamen of one flower to the pistil of another. This is accomplished by two agents, the wind and insects. Accordingly we may divide flowers into two classes, the wind-fertilized (*Anemophilous*) and the insect-fertilized (*Entomophilous*).

No strict line of demarcation can, however, be drawn between these two classes. For, while we find many plants fertilized exclusively by insects and many fertilized exclusively by the wind, there is yet a number of species in which, when the flower first opens, the insects carry the pollen, while later this office is performed by the wind.

In several *Ericaceæ*, of which the Heather will serve as an example, we find fertilization effected in this way. When the flower first opens, the stamens are so enclosed by the corolla that wind-fertilization is impossible, and in pleasant weather

[1] Condensed extracts from "Pflanzenleben." Vol. II. p. 128.

we find the flowers visited by swarms of nectar-seeking insects. Later, however, when the nectar is exhausted, and the insects no longer visit the flower, the filaments lengthen so that the anthers are pushed forward where the wind can seize the pollen and carry it to another flower. Thus, in the economy of nature, if one method of fertilization fail, another is in reserve, and the plant will not have spent its force in vain in producing the flower.

It is, in general, true that the pollen of wind-fertilized plants is very light and dry, like fine particles of dust. We have, nevertheless, the authority of the gardeners that the viscid pollen of the azalea is carried by the wind. Another curious deviation from the usual method of wind-fertilization occurs in a few aquatic plants, in which the viscid pollen is carried by the wind on the reflexed calyx, as in little boats, to the pistil, situated just above the surface of the water. A description of the Eel-Grass (*Vallisneria spiralis*, Fig. 15), an inhabitant of slow-running streams, will serve to explain this method of cross-fertilization.

The ribbon-like leaves of this plant grow wholly submerged in the water and are arranged in whorls at the ends of creeping stems, which grow from the slime at the bottom of the stream. Buds appear

in the axils of these leaves, which give rise either to horizontal, leaf-bearing branches or vertical flower stalks producing either a single fertile flower or a cluster of sterile flowers. The fertile flower consists of a three-lobed pistil, with delicately fringed margins, three minute, inner peri-

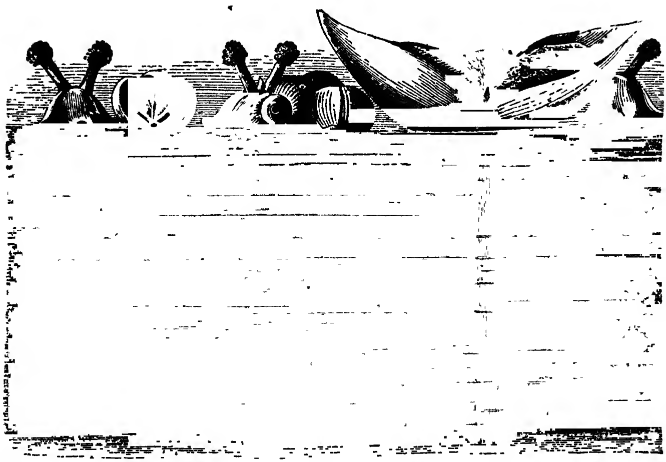


FIG. 15. VALLISNERIA SPIRALIS ("Pflanzenleben").

anth leaves and three large, outer, perianth leaves. When the stigma is mature, the flower-stalk lengthens, the leaves unfold and the flower appears on the surface of the water.

In the case of the staminate flowers, there is no lengthening of the peduncle, but the flowers, when mature, break away from the stem that bears

them and rise to the surface of the water. The perianth leaves becoming reflexed hold the stamens firmly in position while the wind and the currents of water bear the flowers to and fro until they brush against the fringed stigma and deposit some of their pollen. After the pistil has been fertilized, the peduncle contracts spirally and draws the fruit under the water to ripen.

The plants in which the pollen is carried by the wind in the form of dry dust include about one-tenth of all our flowering plants. Among these are found most of our trees that flower in early spring, as the Birch, the Hazel, the Elm and the Alder, the grasses, including the cereals, the sedges, the nettles, the Hemp and the Hop.

It is characteristic of wind-fertilized plants that they have neither a bright color nor an attractive fragrance. The perianth leaves are usually small and inconspicuous, while the flowers have no nectar to entice the insects. Still insects are sometimes seen about wind-fertilized trees, especially the Hazel and Birch, and may slightly aid in cross-fertilizing the flowers, by causing the pendulous catkins to vibrate and so scatter some of their pollen.

. . . .

Most wind-fertilized plants are either monœcious or diœcious, or, if they are perfect, show a

marked dichogamy (that is the stamens and pistil in the same flower mature at different times).

We notice, also, that the flowers which are to be fertilized are always found higher on the plant than those which are to fertilize them. This would seem, at first, to indicate some other method of fertilization than by the wind. Observation shows, however, that the little clouds of pollen, as they are caught up by the wind, are so light that they receive an upward as well as a horizontal impetus, much as, on a dry summer day, we may often see the clouds of dust lifted from the road by the wind and carried along in the air.

In some species of wind-fertilized plants the pollen is projected into the air by the sudden opening of the anthers. We may see a very interesting example of this, if, on a summer morning, we arise early enough to observe a group of Nettles at sunrise. At first we will see here and there a little cloud of pollen arising from the dark-green of the foliage. The explosions soon become more frequent, until one often sees five or six taking place simultaneously. After a little while they diminish in frequency, and in half an hour they have ceased entirely.

In the Mulberry, the stamens have very elastic filaments. At the time of the opening of the

flower these straighten suddenly, expelling the pollen with considerable violence.

The stamens of the grasses have long, slender filaments, which the least breath of air is sufficient to set in motion. Until the pollen is mature the

FIG 16. YEW ("Pflanzenleben").

anther is protected by the surrounding bracts, but, when the time comes for the pollen to be shed, the filament suddenly lengthens, often increasing in ten minutes to three or four times its original length. The pollen escapes through a short slit at

the lower end of the anther, which is upturned to form a sort of cup. As fast as the wind carries away the pollen that is collected in this cup more falls from the upper part of the anther until all is exhausted. Then the anther soon withers and falls to the ground. . . . The growth of the filament and the scattering of the pollen usually occupies from fifteen to twenty minutes.

. . . .

In the Pine and Fir, the upper side of the scale-like connective that bears the anthers is hollowed in such a manner as to form two minute receptacles, which receive the pollen from the flower above. Here the pollen is sheltered from the rain and dew until a favoring wind carries it to a pistillate flower. In the Yew (*Taxus*) (Fig. 16), the connective is circular, with a lobed margin, which fits tightly into the lobes of the adjoining connectives. When the pollen is mature the connective becomes recurved so that the pollen can escape (Fig. 16²). At the approach of moisture and at night the lobes straighten, so as to shelter the pollen.

. . . .

In the Alder, Birch, Hazel and other catkin-bearing trees and shrubs, the upper side of each flower is the receptacle for the pollen from the flower above. In the Pond-weed (*Potamogeton*

crispus) the upper face of the lower petal is curved so as to receive the pollen as it falls from the anthers. In the Arrow-grass (*Triglochin palustris*) the pollen is sheltered in the inflated base of the corolla.

. . . .

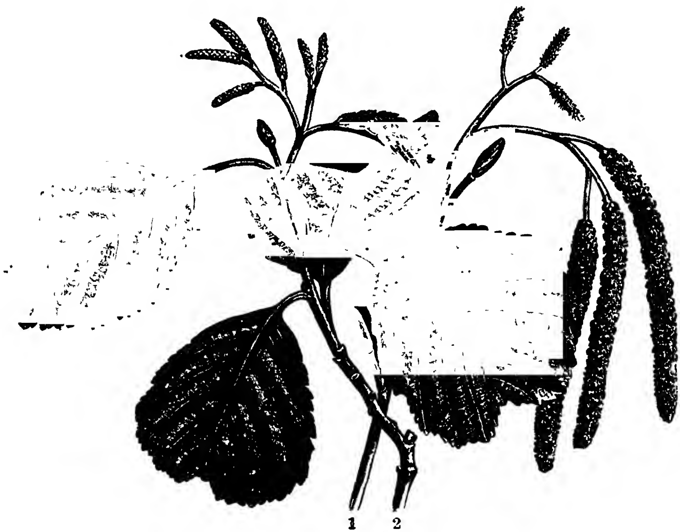


FIG. 17. ALDER ("Pflanzenleben").
1. Branch in spring with ripe catkins. 2. Branch in summer with catkins of succeeding

It is, of course, important that the pollen in its journey from the stamen to the pistil should meet with no obstruction. If the flowers were enveloped by leaves, much of the pollen would be deposited

on them instead of on the pistil and so be wasted. Accordingly we find, either, as in the grasses, the flowers raised above the leaf-bearing portion of the stem, or, as in many trees, the flowers appearing in early spring before the growth of the leaves.

Still the waste of pollen must, of necessity, be very great. A fierce wind may beat upon the blossoms and scatter great quantities of the pollen upon the ground. And also a thousand grains of pollen will pass to one or the other side of the pistil where one will light upon it. So nature has provided such a large supply of pollen that, of the millions of grains carried by a single breath of wind, a few will be sure to reach the pistil and ensure the maturing of fruit.

At the time of the blossoming of the conifers, the pollen is produced in such quantities, that the grass and other plants near the trees become covered with the fine yellow dust, and these showers of pollen have received the name of "sulphur showers."

VIII.

THE FLOWERS OF THE HORSECHESTNUT.

THIS tree is very beautiful in blossom-time. The upright clusters finish the ends of the branches like the candles on a Christmas tree. The timber and nuts are worthless, and the showiness of the blossoms has caused the tree to be used as a symbol of ostentation.

The fertilization of the flowers is extremely interesting. The flower-clusters are terminal, and the type of the cluster is a *thyrsus*. That is, the branches are arranged in a raceme, the lowest branches developing first, while on each branch the terminal flower develops first. In the first case the youngest flowers are at the top of the cluster, in the second the oldest flowers are at the ends of the branches. This is called mixed inflorescence. At first sight, we should think that the youngest flowers were at the ends on the branches also, but it only appears to be so. The lowest flower opened first and was the terminal flower. Then from its pedicel arose a branch also terminated by a flower, and this branching process went on until there

were a number of flowers on a cluster. The method of growth is the same as the leafy branch of the tree where the stronger axillary bud next a flower-cluster throws its mate to one side, making it appear lateral, instead of terminal.[1] This method of growth brings all the flowers on the upper side of the branch (Fig. 18). If it were a raceme with the youngest flowers at the top, the flowers would be arranged around the stem like the branches.

There are a great many flowers on a single thyrsus. The lower branches bear more flowers than the upper ones, for they grow first and have more time to develop, and this makes the shape of the whole cluster a pyramid. There are two kinds of flowers on each cluster. The first ones to mature are all staminate flowers, and have only a tiny rudimentary pistil, which never develops (Fig. $18^{2, 3, 5}$). Later, a little higher on the cluster, appear other flowers with perfect pistils (Fig. 18^{6}), and in these blossoms the style protrudes from the unopened bud, and the pistil develops sooner than the stamens. The later flowers are again staminate, with undeveloped pistils. Generally the pistillate flowers are on the lower half of the cluster, and few will be found at the top, but this varies in different trees.

[1] "Outlines," Vol. I, p. 61.

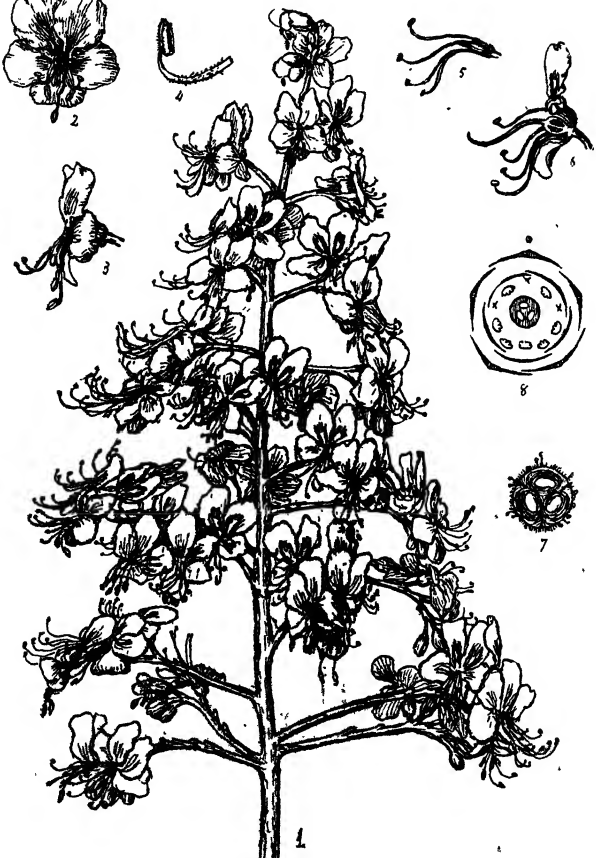


FIG. 18. HORSECHESTNUT.

1. Flower-cluster. 2, 3. Staminate flower. 4. Stamen. 5. Rudimentary pistil and four stamens of staminate flower. 6. Pistillate flower. 7. Cross section of ovary. 8. Diagram.

The nectar in the flower is secreted by a disk under the ovary. The corolla has four or five petals ; when there are but four the lower petal is absent. The nectar is very well protected against the rain. The flower stands in a horizontal position, so that most of the rain will fall on the outside of the corolla. Besides this, each petal has two projections where the blade joins the claw. These projections are pressed around the stamens, which are hairy on the lower half of the filaments, and the whole, corolla, stamens, and all, is pressed tightly against the pistil on the lower side of the flower. This prevents rain from entering and leaves the only path to the nectar under the two upper petals, where it is well protected.

The color of the petals is white with yellow nectar guides, which change gradually to a beautiful crimson. These spots are most conspicuous on the two upper petals which are directly over the path to the nectar, and are hardly present on the lower one, which is far removed from the entrance to the nectar. This change of color makes the whole cluster prettily variegated, the older flowers having crimson, the younger yellow spots, with varying shades of color, according to the age of the flower. The change of color is quite independent of fertilization, but it appears to be utilized by the bees as information which flowers are

rifled of their nectar and not worth visiting, for I have never seen a bee waste his time by creeping into a crimson-spotted flower.

The stamens are usually seven, and are at first bent downwards towards the base of the corolla. They rise one by one as they mature, and, if we happen to be looking at the right time, we can see the anther of a stamen that has just risen split suddenly and become covered with pollen. When this takes place the anther stands directly in the path to the nectar. We have already seen the same arrangement in the *Tropæolum* (chapter II.). The maturing of the stamens singly makes the flower offer its pollen for a longer time, which is a great advantage when we consider how many rainy days there are in spring when the pollen would be injured by wet and the insect prevented from visiting the flower. Also, as only one or two stamens are in the path at the same time, they do not interfere with each other and the pollen is rubbed off clean by the insect. In Fig. 18³, two stamens have risen[1] and will strike the under

[1] The stamens mature in a definite order, or rather in two orders. If we number the stamens, beginning at the upper right hand stamen and going round in the direction of the hands of a clock, the order will be 3, 5, 4, 7, 2, 6, 1, or 5, 3, 4, 1, 6, 2, 7. One of these series is the reverse of the other, that is, if we begin in the second case to number the stamens at the upper left hand stamen and go round in the direction contrary to the hands of a clock, the second series of numbers will be the same as the first. The only way we can explain

side of the body of a bee sucking the nectar. When a bee visits a flower, he alights directly on the stamens, clasping them with his legs, and receiving the pollen on the under side of his body (Fig. 2, upper, middle flower). Our hive bees have a wicked way of crawling about under the flower and sucking the nectar from beneath, thus stealing it without rendering any equivalent, but the humble-bees appear always to visit the flower in the proper way. In the fertile flowers, the style develops before the stamens discharge, curves upwards, and brings the stigma in exactly the same relation to the path to the nectar as the stamens in the staminate flowers. Therefore a visiting insect will bring pollen from the stamens of some other flower and cross-fertilization will be facilitated.

There is a very interesting adaptation in the Horsechestnut, in the buds containing flower-clusters. There are well-developed buds in the axils of the upper leaves, and these begin to grow as soon as the buds open in the spring, and become rapidly growing branches while the flower is still young. Meanwhile the leafy branches with-

this is on the theory that the stamens are arranged spirally, being, in fact, modified leaves, and that in one case the spiral goes from right to left and in the other from left to right. The order follows the two-fifths plan, the three missing stamens belonging to the outer cycle.

out flower-clusters have only latent buds in the axils. The reason of this is evident, for when the flower-cluster drops off the axillary branch is necessary to continue the branch which is stopped. but how does the flower-bud foresee what is to come?

IX.

ATTRACTIVE AND PROTECTIVE COLORS OF FRUITS.[1]

The seeds of plants require to be dispersed, so as to reach places favorable for germination and growth. Some are very minute, and are carried abroad by the wind; or they are violently expelled and scattered by the bursting of the containing capsules. Others are downy or winged, and are carried long distances by the gentlest breeze; or they are hooked and stick to the fur of animals. But there is a large class of seeds which cannot be dispersed in either of these ways, and they are mostly contained in eatable fruits. These fruits are devoured by birds or beasts, and the hard seeds pass through their stomachs undigested, and owing probably to the gentle heat and moisture to which they have been subjected, in a condition highly favorable for germination. The dry fruits or capsules containing the first two classes of seeds are rarely, if ever, conspicuously colored; whereas the eatable fruits invariably acquire a bright color

[1] "Tropical Nature." By Alfred R. Wallace. London: Macmillan & Co. 1878. p. 224.

as they ripen, while at the same time they become soft and full of agreeable juices. Our red haws and hips, our black elderberries, our blue sloes and whortleberries, our white mistletoe berries and snowberry, are examples of the color-sign of edibility; and in every part of the world the same phenomenon is found. Many such fruits are poisonous to man and to some animals, but they are harmless to others; and there is probably nowhere a brightly-colored pulpy fruit which does not serve as food for some species of bird or mammal.

The nuts and other hard fruits of large forest-trees, though often greedily eaten by animals, are not rendered attractive to them by color, because they are not intended to be eaten. This is evident; for the part eaten in these cases is the seed itself, the destruction of which must certainly be injurious to the species. Mr. Grant Allen well observes that the colors of all such fruits are protective, green when on the tree, and thus hardly visible among the foliage, but turning brown as they ripen and fall on the ground, as filberts, chestnuts, walnuts, beechnuts, and many others. It is also to be noted that many of these are specially, though imperfectly, protected; some by a prickly coat as in the chestnuts (Fig. 19) or by a nauseous covering as in the walnut; and the

reason why the protection is not carried further is probably because it is not needed, these trees producing such vast quantities of fruit; that however many are eaten, more than enough are always left to produce young plants. In the case of the

FIG 19 CASTANEA VESCA (Fruit) ("Pflanzenleben")

attractively colored fruits, it is curious to observe how the *seeds* are always of such a nature as to escape destruction when the fruit itself is eaten. They are generally very small and comparatively hard, as in the strawberry, gooseberry, and fig; if a little larger, as in the grape, they are harder

and less eatable; in the fruit of the Rose (or hip) they are disagreeably hairy; in the Orange tribe excessively bitter. When the seeds are larger, softer, and more eatable, they are protected by an excessively hard and stony covering, as in the Plum and Peach tribe; or they are inclosed in a tough horny core, as with crabs and apples. These last are much eaten by swine, and are probably crushed and swallowed without bruising the core or the seeds, which pass through their bodies undigested. These fruits may also be swallowed by some of the larger frugivorous birds; just as nutmegs are swallowed by pigeons for the sake of the mace which encloses the nut, and which by its brilliant red color is an attraction as soon as the fruit has split open, which it does upon the tree. There is, however, one curious case of an attractively colored seed which has no soft eatable covering. The *Abrus Precatoria* or "Rosary Bean" is a leguminous shrub or small tree growing in many tropical countries, whose pods curl up and split open on the tree, displaying the brilliant red seeds within. It is very hard and glossy, and is said to be, as no doubt it is, "very indigestible." It may be that birds, attracted by the bright color of the seeds, swallow them, and that they pass through their bodies undigested, and so get dispersed. If so it

would be a case among plants analogous to mimicry among animals—an appearance of edibility put on to deceive birds for the plant's benefit. Perhaps it succeeds only with young and inexperienced birds, and it would have a better chance of success, because such deceptive appearances are very rare among plants.

The smaller seeds whose seeds simply drop upon the ground, as in the Grasses, Sedges, Composites *Umbelliferæ*, etc., always have dry and obscurely-colored capsules and small brown seeds. Others whose seeds are ejected by the bursting open of their capsules, as with the Oxalis and many of the *Carophyllaceæ*, *Scrophulariaceæ*, etc., have their seeds small and rarely or never edible.

X.

FERTILIZATION OF ORCHIDS.[1]

There is only one true Orchis in this country, and that not common, except northward. And its arrangement for fertilization is not quite so readily understood as in those Orchises which are named by botanists *Habenaria*, of which we have many species. Some of these are plentiful, such as the Fringe Orchises, either the purple, white, or yellow species. The Greater Green Orchis is not so common, but is taken for the present illustration on account of the size of its blossoms. . . . A single blossom, of only twice the size of life, is represented in Fig. 20.

The peculiarities are mainly these: First, the better to attract certain insects and repay them for their service, a separate organ for the nectar — in this instance a long pouch or honey-tube — is attached to the flower. Then, to economize the pollen, the whole of it in each cell of the anther is done up in little packets or coarser grains, which

[1] This extract is taken from "How Plants Behave," by Asa Gray, p. 26. The book is delightful reading for classes, and will be found very useful in the school library.

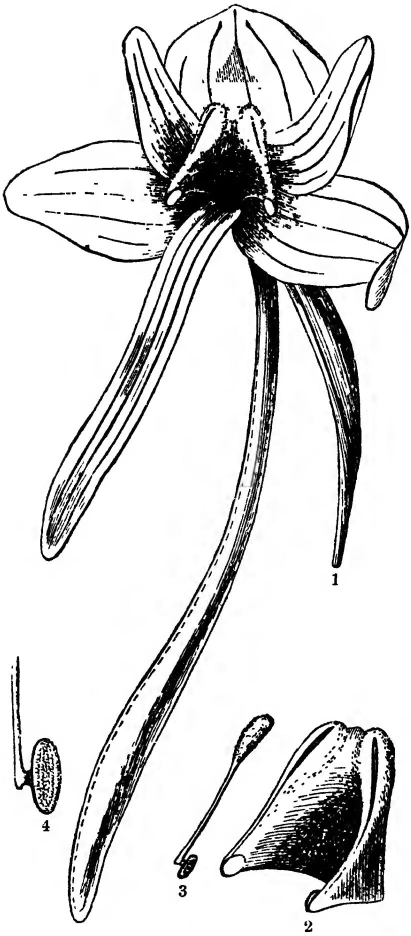


FIG. 20

1 Flower of Greater Green Orchis (Habenaria orbiculata). 2 Its stamen and stigma more enlarged. 3. One of the pollen-masses with its stalk and disk, equally enlarged. 4. Its disk and a part of the stalk more magnified.

are tied, as it were, to each other by delicate elastic threads, and all made fast by similar threads to the upper end of a central stalk. Finally, to make sure of its being taken by the insect and not dropped or lost in the carrying, the other end of this stalk bears a flat disk, commonly button-shaped, the exposed face of which is very sticky; and this is placed just where it will be pretty sure to be attached to the head or proboscis of an insect that comes to drain the honey-tube. So that the insect, on rising from his meal, will probably carry off bodily the whole pollen of that flower (or of one of its anther-cells), and bestow it, or some of it, upon the next flower or flowers visited.

In this particular species, the front petal is, as usual, the insect's landing-place. The other petals are more arching than the front view of the flower in Fig. 20 represents, and obstruct access on all other sides. The long and narrow front petal turns downwards and allows convenient approach. Underneath hangs the honey-tube, its mouth opening just behind the base of this petal. Only the lower half of the tube, more enlarged and capacious, gets filled with nectar. To drain a cup which is about an inch and a half deep requires a long proboscis, much longer than any bee or wasp possesses. Butterflies and moths are our only insects capable of doing it; and one could predict from a view of

the flower that the work is done by them. In fact we have hardly a butterfly with proboscis long enough to reach the bottom of the cup : so we conclude that one of the Sphynxes or Night-moths, such as flock around the blossoms of the largest Evening-Primroses at dusk, is the proper helpmate of the Greater Green Orchis. The Smaller Green Orchis is much like the Larger, but with honey-tube hardly an inch long. This may be drained by many of our butterflies. Some of these have been caught with a remarkable body attached to their great eyes, one on each eye ; on examination this body proved to be quite like that represented in Fig. 20[3], only smaller. This body, as we have seen, is the pollen of one of the cells of an Orchis anther, with its stalk and sticky disk, the latter adhering to the insect's eye. How did it get there ?

The centre of the flower (as in Fig. 20[1]) is occupied by the one large anther, and by the concave stigma. The anther is of two cells, which taper towards the front of the flower and diverge, in this species widely, and the whole space between the two diverging horns on the sides and the orifice of the honey-tube below is stigma, a broad patch of glutinous surface. At the tip of each horn of the anther, facing forwards and partly inwards is the button-shaped, sticky disk. Bring the point of a

blunt pencil, or the tip of the little finger, or anything of the proper size, down into the flower so as to press gently upon these disks for a moment: then withdraw it: the disks will stick fast, and the stalks with the pollen-mass be drawn out of the anther. Now the tip of the finger or the pencil is just in the position which the head of the large butterfly or moth would occupy when its proboscis is thrust deep into the honey-tube. In draining the nectar from the tube the insect's head is brought down close to its orifice, its large projecting eye on one side or the other, or on both at once, is pressed against the sticky button; and when the moth raises its head and departs, it carries away bodily one or both of the pollen-masses. With these the next flowers visited may be fertilized.

Except by the insect's aid as a carrier, secured by this most elaborate and wonderful contrivance, these Orchis flowers could never be fertilized. Close as the pollen is to the stigma, it evidently cannot reach it by any ordinary chance. And it would appear as if the obstacles were not effectually overcome even when a moth or butterfly is so ingeniously employed to convey the pollen from one blossom to another, which is plainly what is intended. For the position of parts is such that when the pollen-masses are extracted by the moth's head, they will stand pointing upwards and for-

wards, as shown in Fig. 21. The stalk is too stiff to allow them to subside by their own weight. So when the moth alights upon the next flower and thrusts its proboscis down its honey-tube, the pollen-masses it has brought would hit the anther, quite above the stigma, and effect nothing. But

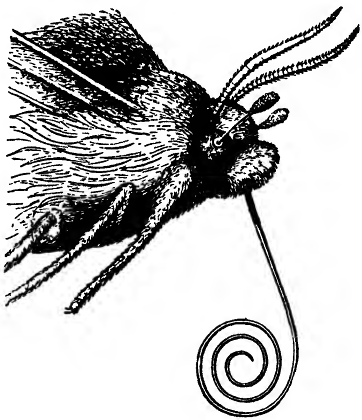


FIG. 21.

Side view of head of a moth (Sphynx drupiferarum), which has just extracted a pair of Orchis pollen-masses.

all this is accurately provided for. As may be seen by watching the pollen-masses when taken upon the point of a pencil, within from ten to thirty seconds their stalk turns downward, as if upon a joint between it and the adhering disk, bringing them into a position like that represented by a

front view in Fig. 22. Now the pollen-masses will accurately strike the stigma!

In some Orchises, and where this adjustment is needful, the pollen-masses on the insect's head not only turn downwards but converge inwards, always in the way and to the degree necessary for their striking the stigma. In the larger Green Orchises, from which the illustrations are drawn, the sticky disk is almost parallel with the stalk of

FIG 22.

Front view of the same, with the pollen-masses in the position they soon take. Both figures magnified to the same degree as is the orchis flower in Fig. 16.

the pollen-mass at its lower end, and attached to it by a short intermediate joint, as shown in Fig. 20^3, and more magnified in Fig. 20^4. It is nearly the same in the Yellow and the White Fringed Orchises, which flower later in the season. In all these the disks face partly inwards, at considerable distance apart, and are stuck to the eye of the butterfly that visits them. In others the disks are borne directly upon the end of the stalk, are gener-

ally closer together, and get applied to the front of the head, or sometimes to the proboscis of the insect.

When a pollen-mass, thus carried on the head of an insect, is brought into contact with the stigma, some of the pollen will cleave to its glutinous surface and be left there, the little threads that bind it to the stalk giving way; another portion will be left upon the stigma of the next flower visited, perhaps on the next also, and so nearly all the pollen be turned to good account. Sometimes the adhesion of the disk to the insect's eye is less strong than the threads that bind the grains to the stalk on the one hand, and than the adhesion to the stigma on the other. Then the whole pollen-mass is left upon the stigma of that flower, and its pollen taken in turn, to be exchanged for that of the next flower; and so on. In any case each blossom will be fertilized by the pollen of some other blossom, which is the end in view; and a more ingenious contrivance for the purpose cannot be imagined.

The student should see all these curious things with his or her own eyes, in order fully to comprehend and enjoy them. Once understood in our common wild Orchises, it will be equally interesting to find out how it is done, in more or less different and varied ways in other Orchids. . . .

In Lady's-Slipper, or Cypripedium, the plan for securing fertilization is so different from that of any other of the Orchis Family as to need a separate description, but a very brief one must serve. We refer to our wild species; and first to the yellow ones and to the large white and pink one, *Cypripedium spectabile*, the Showy Lady's-Slipper (Fig. 23). Unlike other Orchids, there are two stamens: the pollen is powdery, or between powdery and pulpy, and not very different from that of ordinary flowers. As it lies on the open anther in a broad patch, it somehow gets a film like a thin coat of sticky varnish. The stigma is large, flat, and somewhat trowel-shaped, the face turned forwards and downwards (Fig. 23^g): it is supported on a stout style, to which the anthers have grown fast, one on each side (Fig. 23^h). This apparatus is placed just within the upper part of the sac or slipper (rather like a moccasin or buskin than a slipper), which gives its name to the flower. There are three openings into the slipper; a large round one in front, and the edges of this are turned in, after the fashion of one sort of mouse-trap; two small ones far back, one on either side, directly under each anther. Flies and the like enter by the large front opening, and find a little nectar apparently bedewing the long hairs that grow from the bottom of the slipper,

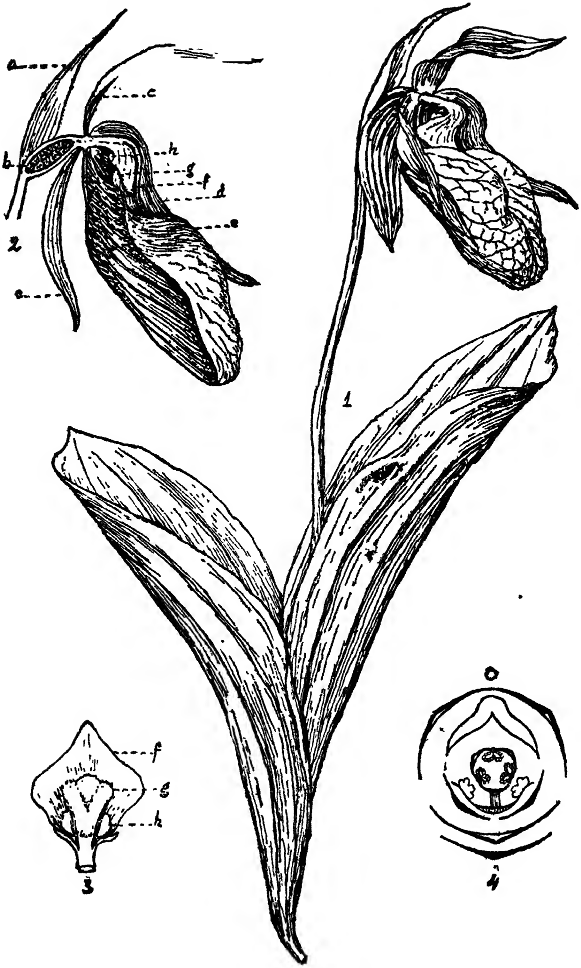


FIG. 23. LADY'S SLIPPER.

1. Flower-stalk and leaves. 2 Section of flower: a, bract; b, ovary; c, sepals; d, lateral petal; e, lower petal (lip); f, upper stamen; g, stigma; h, lateral stamen 3 Upper stamen, with lower fertile stamens and stigma. 4. Diagram.

especially well back under the overhanging stigma. The mouse-trap arrangement renders it difficult for the fly to get out by the way it came in. As it pushes on under the stigma it sees light on either side beyond, and in escaping by one or the other of these small openings it cannot fail to get a dab of pollen upon its head, as it brushes against the film with which the surface is varnished. Flying to the next blossom and entering as before, as the insect makes its way onward, it can hardly fail to rub the pollen-covered top of its head against the large stigma which forms the roof of the passage. The stigma of every other Orchid is smooth and glutinous. This is merely moist and finely roughened: the roughness comes from very minute projections, all pointing forwards, so that the surface may be likened to that of a wool-card or of a rasp on a very fine scale. So, as the insect passes under, the film of pollen is carded or rasped off its head by the stigma and left upon it; and when the fly passes out it takes a fresh load of pollen on its head with which to fertilize the next flower. This mode of action we first predicted from an inspection of the flower and a simple experiment. It has since been confirmed by repeated observations. The early-flowering and purple stemless Lady's-Slipper differs from the others in having its larger slipper or sac pendent, and with a long slit in front,

instead of a round open orifice; the two lips of the slit are mostly in contact, but the fly may readily push its way in; the way of exit is more open than in the other species.

XI.

WEEDS.

SOME AMERICAN COLONISTS.[1]

The commonest weed in this little English garden at the present moment is a small creeping Wood-Sorrel, with the characteristic Shamrock leaf (for Wood-Sorrel, not Clover, is the true trefoil of St. Patrick and of Ireland[2]), but bearing yellow blossoms instead of the pretty lilac-veined petals of our own familiar spring species. It is an interesting little plant in its own way; for, contrary to all the natural traditions of emigration, it has moved eastward, against the way of the sun, and

[1] "Colin Clout's Calendar." By Grant Allen. London. Chattc & Windus, Piccadilly, 1883, p. 221.

[2] "The plants that for a long time past have been regarded by the Irish as the true Shamrock, and worn by them on St. Patrick's day, are the Black Nonsuch (*Medicago lupulina*) and the Dutch Clover (*Trifolium repens*), and these, but chiefly and almost exclusively the first, are sold for the national badge in Covent Garden, as well as in Dublin. Intermixed with them are several other species of the same two genera, *Medicago* and *Trifolium*; but no plant of any other genus. Of late years, however, several writers have adopted Mr. Bicheno's fancy and advocated the claims of the Wood-Sorrel to this honor, but certainly without the slightest shadow of reason." "Popular Names of British Plants." By R. C. A. Prior. p. 213.

has come to us across the Atlantic from the broad central plains of the American continent. There is something strange in the notion of a weed from the New World overrunning the fields of the Old, and living down the native inhabitants of more anciently civilized Europe. Of course, we all take it for granted that our own Thistles, Chickweeds, and Groundsels ought rightfully to accompany British Wheat and Barley to every part of the colonizable world: indeed, the North American Indians call our common English Ribwort "White Man's Foot," because they say it springs up naturally wherever the heel of the pale faces has trodden the soil. Sir Joseph Hooker found our weedy English Shepherd's Purse — itself a colonist from Central Asia — growing abundantly over a solitary antarctic islet; and traced it finally to a single seed which must have clung accidentally to the spade used to dig the grave of a sailor, around which the intrusive little plant was observed to flourish in great luxuriance. Such facts as these we all know and expect: it seems fit and proper that the familiar weeds of cultivation should follow civilized tillage on its widening way over the world. But we are more surprised when we find that a good many American weeds have also forced their way eastward — against the stream, so to speak — and have invaded the Old World, *en revanche*, with the po-

tatoes and the maize, achieving such success as to have lived down more than one of their European compeers. In Southern France and Italy the number of these eastward immigrants is very considerable ; and even in wetter and chillier England, a poor foster-mother for children of the basking American plains, it is far from being either small or unnoticeable. Such cases are not in themselves at all more remarkable than those of the phylloxera, which has already made good its footing in Europe, or of the Colorado Beetle, which we are now endeavoring feebly to repel ; but they seem more curious at first sight, because the aggressiveness of fixed and unconscious plants is harder to understand than the aggressiveness of locomotive and volitional animal organisms.

Two of these American Wood-Sorrels, both with yellow flowers,[1] have now made themselves a permanent home in England, and have even conquered their admission within the exclusive lists of the British flora. One of them has long been a universal weed in all hot climates of the globe and in most temperate ones, having followed the Tobacco plant to Syria and Java and accompanied the Tomato to all the warmer climates of Mediterranean Europe. In England it appears chiefly in the southern counties, and does not thrive well in the

[1] *Oxalis Corniculata* and *O. corniculata, var. stricta.*

midlands or the north. But some other American weeds have had better luck among us; such, for example, as the tiny white Claytonia, a straggling round-leaved succulent plant, not unlike the garden Purslanes.[1] This queer little tufted trailer, a familiar weed in American gardens, has thickly overrun many parts of Lancashire, having doubtless been landed at Liverpool. In another direction, it has effected an entry by the port of London, and spread in abundance over many parts of Surrey, besides making little excursions up the river to Oxfordshire and attacking several of the neighboring counties on its onward march. It is still rapidly advancing; and though but a naturalized alien, it threatens before many years to become one of our most annoying and persistent garden-weeds.

A rather pretty American Balsam, with orange blossoms spotted with red,[2] has in like manner made itself a firm local habitation on the banks of the Wey and sundry others among the Surrey streams. Then there is the Canadian Michaelmas Daisy, long completely naturalized on the Continent, and now beginning to push its way boldly along the grassy margin of southern English roadsides. All these are thoroughgoing weeds, extremely troublesome in America itself as well as in the European

[1] Probably *Claytonia perfoliata.*

[2] *Impatiens fulva.*

countries where they have established themselves; and they are rendered dangerous by the fact that they come from a very large continent mainly consisting of open prairie, which ensures them excellent weedy constitutions, as the final survivors in an exceptionally severe struggle for existence among highly adapted prairie plants. They have come across to us by accident as mere weeds, clinging to the tubers or roots of imported food-plants. Somewhat different is the case of ornamental blossoms like the Mimulus, originally planted in flower-gardens, but now fairly established as an escape in boggy or marshy ground. Of these handsome straylings we have several acclimatized varieties; but they do not spread like the regular weeds, nor have they the same strength of constitution which enables the Claytonia and the Michaelmas Daisy to compete successfully with the old-established weeds of cultivation in southern Europe.

Even more interesting, however, than these aliens, which owe their introduction directly or indirectly to man, are the real natural colonists from America, which are found sparingly in many places along our exposed western coasts, from the Hebrides to Cornwall. Many of them, no doubt, have been acclimatized in Britain long before the discovery of America by the Spaniards; for all the

evidence goes to suggest that their seeds must have been carried across the Atlantic by the agency of sea-birds, or must have been wafted over in the crevices of drift-wood, or must have been washed ashore by the favoring current of the Gulf Stream. For example, in the lakes and tarns of the Isle of Skye, Coll, and the outer Hebrides, as well as in the shallow loughs of Connemara and Kerry, a slender graceful water-plant with pellucid leaves grows abundantly over the soft mud, and forms a tufted waving carpet above the smooth shining bottom, with its white jointed fibres and grass-like blades. This pretty weed belongs to a family otherwise wholly unrepresented in Europe, but common in all the still waters of America. Clearly, from the nature of its distribution here — only along the extreme western belt of the British Isles, where the coast lies fully exposed to the long wash of the Atlantic — it must have reached our shores by some such casual accident as those which have peopled oceanic islands, like the Azores, with their scanty fauna and flora. Its seeds must have clung to the legs of wading birds blown eastward before a northern cyclone, or else its roots must have been torn up entire and cast upon some shelving Irish coast by westerly winds. Similarly, in a few Connemara pools, as well as in two or three Continental stations, another pretty little American water-

plant, classically named the Naiad,[1] has long grown in isolated colonies, cut off by the Atlantic from the main body of its race in Massachusetts and Labrador. A beautiful small white orchid, too, distantly allied to our common English Lady's-Tresses, abounds all over the eastern half of North America; but in Europe it is known only in a few bogs in county Cork, where the ardour of modern botanists is rapidly putting an end to its brief European career. This case presents some features of peculiar interest, because the Irish specimens seem to have been settled in the country for a very long period, sufficient to have set up an incipient tendency towards the evolution of a new species; for they had so far varied before their first discovery by botanists that Lindley considered them to be distinct from their American allies; and even Dr. Bentham originally so classed them, though he now admits the essential identity of both kinds. The blue Bermuda Grass-lily, again, a common and extremely graceful American meadow-weed, is found in one place only in Europe; and that is near Woodford, in Galway, where it does not appear to have been introduced by human agency.

[1] The only species mentioned in the British Flora is *Naias flexilis*. Dr. Gray gives this plant as of European origin, but mentions a variety, *Var. robusta*, as native in Massachusetts.

It would even have been possible before the days of Columbus for a philosophical botanist of the modern type (had one then been imaginable) to have predicted the existence of the American continent from the occurrence of so many strange plants in isolated situations on the western shores of Britain and Scandinavia. He would rightly have argued that these unfamiliar weeds, not belonging to any part of the European flora, and sometimes even differing wholly from any known family of European plants, must have come with the prevailing winds and currents from some unknown land beyond the sea. That the plants in question grew there even then is highly probable, because most of them bear every sign of great antiquity; certainly they are not likely to have been introduced by man, since the larger number are mere inconspicuous water-plants, which could not come over with cultivated seeds or tubers, and which would not, of course, be deliberately planted in gardens. On the other hand, when once introduced by chance, they would be sure to gain a firm footing; because America, with its enormous stretches of fresh water, in rivers, lakes, and innumerable scattered ponds, is far richer in strong and well-endowed aquatic weeds than relatively hilly and lakeless Europe. This peculiarity is well seen in the career of the Canadian Pondweed,

which was first introduced into England as a botanical specimen in 1847, and rapidly spread through canals and sluggish waters over the whole of Britain. No European weed can stand against it; and what makes its progress the more remarkable is that it seldom or never seeds in this country, propagating entirely by its lissom floating rootless branches. Still, the area over which it has made its way, and the centres from which it started —Yorkshire, Leicestershire, Berwick, and Edinburgh — clearly show (what is otherwise well known) that it owes its introduction to human means: while the spontaneous occurrence of the other water-plants in a few lonely portions of the western coasts equally suggests that they owe their transplantation solely to birds or ocean-currents.

PESTIFEROUS PLANTS.[1]

Some plants, naturally, are better fitted to subserve the wants of man than others, and for the growth of these he puts forth special effort; in short, the whole underlying foundation of modern agriculture rests upon methods of favoring these plants and thereby enlarging and multiplying those qualities in them that led to their being chosen by

[1] Popular Science Monthly, June, 1892. "Pestiferous Plants," by Byron D. Halsted.

man as objects of cultural attention. All plants, therefore, that now legitimately occupy space in our fields, orchards, and gardens, are living an unnatural life, because they are in part creatures of selection and care; and it therefore follows that, owing to this stimulus under which they have flourished for generations, when the fostering hand of man is withheld they either perish or gradually drift back to the wild state, and slowly lose many of their most valuable qualities as cultivated plants and regain those that better fit them for the stern battle of life. During the time while cultivated plants have been brought to a high plane of usefulness there have been many other species with no merit in their products that have stood in the way of the development of these fostered plants. The weeds have grown strong because obliged to fight their way and take every possible advantage when opportunity offered. They quickly win in the race for supremacy in every field devoted to cultivated crops, when man's care is withheld, and multiply their kind to an extraordinary extent. More reasonable it would be to expect a man under the softening influences of civilized life to win in the rough race for existence when placed, unaided, among the savage Indians, than to hope for the success of a Parsnip or Onion seedling when surrounded by a rank growth of weeds.

There is nothing in the structure of a plant that Cain-like curses it forever. No part of the leaf, stem, fruit, or flower gives conclusive evidence that it belongs to a weed, and therefore we are forced back to the definition that was accepted a long time ago, namely, "a weed is a plant out of place." Its relation to others makes a plant a weed. A rosebush of the rarest variety and one highly prized in its proper place, is a weed when occupying the soil to the detriment of some other plant that has the authorized right to the soil. Clover, and the best of grasses may be serious weeds, fit subjects to be uprooted by the cultivator or hoe, when growing in the cornfield and injuring the maize crop. If a field is devoted to wheat it follows that all other plants therein may be weeds, whether it be Cockle, Redroot, or an Oak tree.

There is a possibility of any kind of plant being a weed, but this thought does not prevent some species always being out of place. For example, there is no function in the economy of the farm garden that the Canada Thistle can do as well as many other plants. As a forage plant, or a source of nutritious seed or beautiful flowers, the Pigweeds are a substantial failure, equaled only by their success in occupying the soil and robbing it of nourishment designed for useful plants. It would puzzle anyone to find a proper place for the

Horse-Nettle, now advancing upon the eastern farmers from the southwest, and destined to spread its horrid, prickly, worse than worthless branches over our cultured soil. The Bur-grass, Cockle-burs, Burdock, and a long list of congeners are practically universal every-day curses, from which all earnest crop-growers wish to be free.

The natural covering of a fertile soil is a growth of vegetation. Upon the broad, open prairie there is a dense coat of grass, while in the Eastern States a heavy growth of trees clothed the virgin soil. So strong is Nature's desire to assert this right that if we allow one of our fields to lie fallow, at the end of the season it will be covered with vegetation. She understands that a bare soil is a wasteful soil, for while it is not producing anything it may lose by leaching much fertility already in its bosom. Every generation of plants inherits the deposits of all previous generations, and in turn should add to the accumulated stock already in the soil. By this economical and saving practice of Nature the fertile newly-broken grass lands have been made, while the upper soil in the forest has received the enriching accumulation of ages. Man overturns this harmonious system, and breaking up the sod destroys the very method by which sod is made. He clears away the forest and many of the conditions which favor the growth

of trees. It is upon this newly exposed soil that weeds assert their supremacy, and if the hand of man is withheld they will soon weave a garment, in itself unattractive, that clothes the bare earth. Weeds have a thousand ways of doing this to one possessed by cultivated plants. Bring up, if you please, some soil from the bottom of a newly dug well, and if exposed for a season some weeds will have planted colonies upon the bare heaps, and vied with each other for the entire possession of the new territory, at the same time gaining forces for the occupation of any similar place elsewhere.

The crop grower necessarily introduces the condition of a bare soil for a portion of the year for every crop, and must therefore accept the situation; while he invites their presence and development, even stimulating them in various ways by making the conditions favorable for the growth of his crop plant, he must become a competitor with the weeds for the possession of the soil. The weed seeds are either in the soil or soon find an abundant entrance, and if the way is clear the young pests are up and doing as with the morning sun.

Most of our weeds, like much of our vermin, have come to us from beyond the sea. Just how they emigrate in every case will never be known; some came as legitimate freight, but many were "stowaways." Some entered from border lands

upon the wings of the wind, on river bosoms, in the stomachs of migrating birds, clinging to hairs of passing animals, and a hundred other ways besides by man himself. Into the New England soil and that south along the Atlantic seaboard the weed seeds first took root. Also the native plants, with a strong, weedy nature, developed into pests of the farm and garden. Many of the native weeds are shy and harmless in comparison with the persistent and pugnacious ones that have, like vagabonds, emigrated to our shores. Why should it be that plants of another country not only find their way here, but after arriving assert themselves with a vigor far surpassing our native herbs? Dr. Gray, in writing upon this point, says: "As the district here in which the weeds of the Old World prevail was naturally forest clad, there were few of its native herbs, which, if they could bear the exposure at all, were capable of competition in the cleared land with emigrants from the Old World." European weeds had through long ages adapted themselves to the change from forest to cleared land, and were therefore prepared to flourish here in the rich forest soil that was suddenly exposed to the sun and subjected to other new conditions by the felling of the trees. To go back of this, we are not sure that the ancestors of some of our European weeds ever came from the forest, but

instead were brought into the cleared-up lands from the open regions in the early days of agriculture in the Old World. As civilized man moved westward, the weeds followed him, reinforced by new native ones that soon vied with those of foreign blood. Not satisfied with this, these natives of the interior ran back upon the trail and became new enemies to the older parts of our land. The conditions favorable to the spreading of weeds have increased with the development of our country, until now we are literally overrun. Weeds usually, as seeds, go and come in all directions, no less as tramps catching a ride upon each passing freight train, than in cherished bouquets gathered between stations and tenderly cared for by transcontinental tourists in parlor cars. "Weeds," Burroughs says, "are great travellers . . . they are going east and west, north and south, they walk, they fly, they swim . . . they go underground and they go above, across lots and by the highway. But, like other tramps, they find it safest by the highway; in the fields they are intercepted and cut off, but on the public road every boy, every passing herd of sheep or cows, gives them a lift." They love the half-earnest tiller of the soil, and will crowd around his barns and dwelling and flourish in his garden and fields so long as he favors them with slight attention to his crops.

XII.

THE COMMON DANDELION.

In the various names which the Dandelion has received, we see expressed, for the most part, either a reference to the tooth-like recurved lobes of the leaves (Fig. 23) or an allusion to the medicinal properties of the plant. Thus, our English name is a modified form of the French *dent de lion*, meaning the lion's tooth, and in German we have the same idea expressed in *Löwenzahn*. Fifty years ago this plant appeared in the botanies as *Leontodon taraxicum*, the generic name being derived from the Greek *leon*, lion, and *odons*, tooth, and the specific from the Greek *tarasso*, to stir up, in reference to the effect of a dose. In later works we find the genus *Leontodon*, including the "fall Dandelion" (*L. autumnale*), but not the true Dandelion, which now appears in a genus by itself under the name *Taraxicum Dens-leonis*. Here the specific name is merely "lion's tooth" again, in Latin.

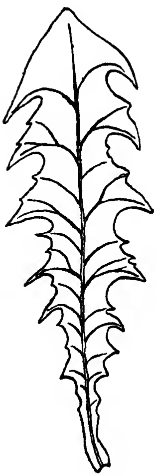


FIG 23.

Finally, in the latest works our plant is given as *Taraxicum officinale,* since this has been found to be the name which, according to the rules of botanical nomenclature, takes precedence of all others. An allusion to the teeth is thus no longer retained, the only reference remaining being to the plant's official use.

To the majority of people the mention of the Dandelion calls to mind not so much its medicinal properties as its use for food. Although its cultivation, either as a spring potherb or as a salad with blanched leaves, is comparatively modern, the wild plant seems to have been long valued as a vegetable. There is reason to believe that the Romans made use of it as a potherb, and Chinese writers of the fourteenth century mention its being eaten in their country, although there is no evidence of cultivation at that time.

There are but few of our flowering plants that grow so widespread over the world. It occurs in North America from the Atlantic to the Pacific coast, in Europe, in Asia, and in the arctic regions. This extensive range may in part be accounted for by the fact that our plant belongs to the large and aggressive family of the *Compositæ,* and is thus related to such invaders as Daisies, Burdocks, and Thistles. Still, the Dandelion has more to recommend it than mere family connection : for, despite

its lowly aspect, it is no poor relation ; but, as we shall hope to show in the present article, it has many virtues of its own which entitle it to respect.

Prominent among these is its adaptability to the different conditions under which it grows. It seems to make the best of everything. If by chance a seed falls upon poor, thin soil, the young plant sends forth, as rapidly as possible, a rosette of leaves pressed close to the earth ; and thus, on the principle that "possession is nine points of the law," it secures for its roots the use of a certain amount of territory quite safe from the encroachments of other plants. In rich ground the case is quite different, for here there is so much nutriment in a small quantity of earth, that the struggle for soil is not such a life-and-death matter as in the less favored localities. Consequently we find a large number of plants crowded together as close as they can stand ; and it is obvious that if, under these circumstances, the Dandelion should develop a flat rosette of leaves, the grass and other plants growing around would soon overshadow it, and it would have small chance for life. Our plant therefore extends its leaves upwards, and does its best to elongate them so as to keep pace with the growth of its rivals. But as these are for the most part grasses and plants which grow by elongation of the stem, the race for sunshine is rather in

favor of these other plants, for the reason that a given amount of material put into a stem makes a stiffer organ than when put into a leaf. Still, even with these odds against it, the Dandelion seems well able to hold its own ; for it probably derives more or less advantage from the recurved lobes, or teeth, which give the plant its name. These are admirably fitted to act in much the same manner as a ratchet ; and when the neighboring grasses are blown against the Dandelion, a blade may slide along the margin of the leaf toward the base ; but, as it springs back from its own elasticity, it cannot slide in the opposite direction, for a tooth will catch it, and thus force it to help support the leaf, and hold it up to the sunshine. We need not stop to consider how the Dandelion behaves in soil which is neither very rich nor very poor, for enough has been said to show that it has not much to fear from any rivals it may meet under ordinary circumstances.

It is not only against the aggressions of neighboring plants, however, that our Dandelion needs to be prepared : it is at least equally important for its welfare that it have some means of protection against herbivorous animals — not only such as might eat its leaves, but also the more stealthy ones that live upon the food which plants store underground. All such foes it thwarts by a means

as simple as it is efficient. Every part of the plant contains a milky juice which is intensely bitter, and a first taste is quite enough to convince the most stupid animal that raw Dandelion is not good eating, and most animals know enough to let it severely alone. Curiously enough, however, in this, as in many other cases, it happens that what in nature acts to deter animals from eating the plant, with man offers the chief attraction, for it is this very bitter principle (*taraxicine*) which gives to Dandelion greens their peculiar flavor, and affords the essential element in the extract which physicians prescribe.

The store of food, referred to above, which the Dandelion accumulates in its root, not infrequently enables it to pass, almost unharmed, through dangers that with less provident plants would surely prove fatal. For example, it must often happen that from drought or from being trampled upon by animals, the leaves become wholly or in part destroyed. Now, if there were no reserve store of food, the plant would have no chance of rallying ; but, as it is, this food supplies the material for new growth, and upon the return of favorable conditions, fresh leaves are developed, and the plant lives on as before. Primarily, of course, the purpose of this storage of food is to enable the plant to live on from year to year, resting in the winter,

and in the spring beginning work again with a good start.

In comparing the higher with the lower plants, the superiority of the former is most beautifully shown in the better provision which is made for the welfare of offspring ; and in this regard our Dandelion stands among the highest. Before we can understand the ways in which our little plant performs this part of its life-work, we must briefly consider the structure of the blossom.

If with a sharp knife we cut a blossom in halves, from the stem upwards, the parts represented in Fig. 24. will be disclosed. Surmounting the stalk

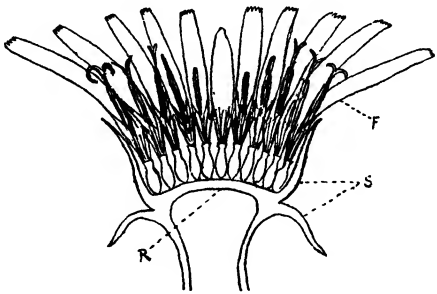


FIG. 24.

is a cushion-like receptacle (*R*), from the top of which arise a number of tiny flowers (*F*); while from the side grow out a series of green scales (*S*), forming an involucre around the whole. A single one of these florets (Fig. 25) exhibits the following

parts : first, a bright yellow corolla (*CO*), tubular below, but strap-shaped above, as if a tube had been split for part of the way on one side, and the upper part flattened ; second, five stamens (*SN*), attached by slender filaments (*FM*) to the tubular part of the corolla, and with their anthers or pollen-sacs (*AN*) joined together by the edges to form a tube ; third, a single pistil having a long style (*SY*), which, above, passes through the anther-tube, and bears at its end two diverging stigmas (*SG*), and below connects by a short neck (*N*) with the small ovary (*O*), which contains a solitary ovule ; fourth, a calyx (*CX*) composed of numerous slender bristles.

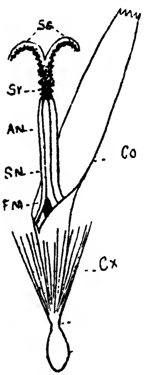


FIG. 25.

The purpose of these complex structures is, of course, in one way or another to secure the development of the ovule into a seed fitted to produce a new plant. This development will proceed only after the ovule has been influenced (i.e., fertilized) by pollen placed upon the stigma ; but when once the mysterious process of fertilization has taken place, then there follows immediately those wonderful changes in the blossom which culminate in the ripening of the fruit.

There are but two possible ways in which fertilization may be secured : either the pollen which

affects the ovule must come from the same flower (then called close-fertilization),or the pollen must come from another flower of the same kind (cross-fertilization). Now, while either of these methods will insure the production of a seed, numerous experiments go to show that those offspring which result from cross-fertilization are in many ways superior to those which are produced from close-fertilization ; and it is to the advantages of cross-fertilization that we have to look for an explanation of the significance of many peculiar structures, not only of the Dandelion, but of flowers in general.

It is obvious, that, to secure cross-fertilization, there must be some agent to transfer the pollen from one plant to another. Most commonly, either the wind is taken advantage of for this purpose, as with Elms, Pines, Grasses, etc., or else flying insects are induced to perform the office, as is the case with the majority of our familiar flowers. The wind is a very wasteful carrier, so that for every grain that is properly placed, thousands, or even millions, may be lost. Insects, on the contrary, waste but little; and, moreover, as Aristotle so shrewdly observed, they habitually confine their visits, for a number of trips, exclusively to the flowers of one species.

The Dandelion seems to fully appreciate the great advantages of securing the services of insects,

for it appeals most strongly to their love of bright colors and their passion for sweets. As the flowers open, each tiny golden cup is filled to the brim with purest nectar; and he must be a very dull insect, indeed, that cannot see the brilliant head of flowers as far as he can see any thing At any rate, it is not the Dandelion's fault if he does not, for the blossom is placed where it will be as conspicuous as possible. If the surrounding herbage is tall, the flower-stalk is elongated, so that the crown of flowers may not be obscured. If the plants around are low-lying, it would be wasteful to have a long stalk, so it has a short one, — sometimes so short that the blossom looks like a button in the centre of the leaf rosette. Economy of material is furthermore shown in the fact that the stalk is always hollow, — for it is a principle well known to builders, that, when there is required a pillar of a given strength, less material is needed for the tubular form than for the solid cylinder.

But to return to our flower. We have next to consider how the visits of insects are utilized to secure cross-fertilization. If we examine the anther-tube of a flower that has just opened (Fig. 26), we shall see that the style has not yet protruded, but fills the entire cavity, except such space as is occupied by a quantity of pollen which the anthers have shed. So much of the style as

is within the tube is thickly beset with hairs that point upwards; and when the lower portion elongates, this hairy part brushes the pollen out of the tube, and protrudes, covered with the yellow dust (Fig. 27). At this stage, an insect coming for nectar must rub against the style, and so become more or less covered with pollen. None of it, however, can get upon the stigmas, for they are not yet exposed. After a short time has elapsed, during which much of the pollen has probably been rubbed off, the style is seen to split at the top; and as the halves separate and roll back (Fig. 25), their inner faces (the stigmas) are exposed. If, now, the flower be visited by an insect which has previously been to a younger flower, the pollen he brings will be deposited upon the stigmas as he rubs against them, and cross-fertilization will be effected.

FIG. 26.

FIG. 27.

Let us suppose, however, that no insect visits the blossom, — and this must often happen to such as appear very early in the spring or late in the fall, when hardly any insects are around. In such cases we find that seeds are produced, and therefore we must infer that fertilization has in some way or other been secured. An examination of a flower

still older than any we have considered (Fig. 28) will show us what takes place. Here it will be seen, that, after the stigmas have diverged, they continue to

FIG. 28

roll back, until a coil of one or more turns has been made; and as a result of this the stigmatic surface comes in contact with the hairs on the style, and touches the pollen grains entangled by them. Still, the close-fertilization thus accomplished is only a last resort, and it can only occur in the event of insects' visits having failed ; for when pollen from another flower has once fallen on the stigma, no pollen coming afterwards can have the least effect. Thus, we have another instance of the Dandelion's ability to make the best of its surroundings.

It even adapts itself to the weather; for when the sun shines, the scales of the involucre bend back, and the blossom is expanded to its fullest extent; but in dull weather, or at night, the scales bend inwards, and the blossom is tightly closed. The advantages of this remarkable movement, with its implied sensitiveness, is obvious when we consider that insects are abroad only in sunshine, while at other times there is danger of dew or rain getting into the nectar, and so spoiling it for the insects.

After fertilization has been accomplished throughout the blossom, the involucre closes, and remains closed during the ripening of the fruit. The changes which now take place are as follows: In each flower the corolla, stamens, and style, being of no further use, wither, and sever their connection with the ovary; the ovule develops into a seed containing a tiny plantlet well provided with food for its use during germination; the ovary grows to keep pace with the seed, its tissues become hardened, and a number of spine-like projections develop near the upper part; and finally the short neck which bears the calyx bristles elongates, pushing upwards the withered parts of the flower. At this stage the involucral scales bend back through an arc of about 180°, the cushion-like receptacle becomes almost spherically convex, the fruits radiate in all directions, the bristles spread, and a beautiful cluster of little parachutes is presented to the wind.

Even a glance at one of these fruits (Fig. 29) is sufficient to discover a wonderful fitness for transportation by wind, and more careful study shows that this fitness pervades every detail. For example, on examining the bristles microscopically (Fig. 30), it is shown that they are not simple threads, but each is hollow and has numerous projections extending on either side, all of which

serves to increase the buoyancy in a very effective way.

The experience of aeronauts has shown that a highly important part in the equipment of a balloon, after the attainment of buoyancy, is the provision of some means of arresting the balloon's progress when the destination has been reached. One of the most successful means which they employ is the grappling hook; and as we find the base of our diminutive parachute provided with a number of upwardly directed spines, it seems fair to conclude that these serve to arrest the fruit upon favorable soil. If it comes to rest upon a smooth surface,—which, of course, would be barren,—the next breeze would easily blow it away; but if it chance to fall on soil or among other plants, the effect of the spines would be to retain it against the power of even a strong wind. Thus, we may leave it safely landed upon good soil, ready to begin, under favorable conditions, the cycle of its wonderful life.

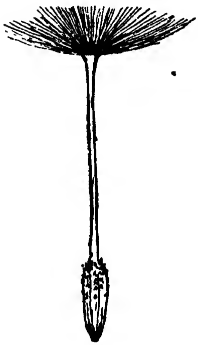


FIG. 29.

FIG 30

XIII.

HOW SEEDS TRAVEL.

Plants seem to share with animals the desire to perpetuate themselves in their offspring. If we allow our Sweet Peas and our Pansies to run to seed we shall have but a short season of flowers. The plant's purpose is accomplished when sufficient seed is formed, and the rest of the season is spent in perfecting it and making it ready to carry the life of the parent into new individuals. We are struck with wonder when we consider the beautiful adaptations that exist to protect the seeds while they are ripening and to disperse them when they are matured.

In our common flowering plants, such as we are about to consider, the seeds develop in a closed ovary, which ripens into the fruit. Within the seed is a plantlet, which will be a new plant, if it succeeds in finding the right place to begin its life. In the same small space, Nature has packed away nicely prepared food to support the plantlet, till it has a root and can earn its own living from the soil and air. We often make use of this

food, and our bread and coffee, our buckwheat and cocoa are stolen directly from the tiny embryos for which the nourishment was stored. So is the cotton-seed oil, which in bottles of green glass masquerades in all our houses as olive-oil, linseed oil, taken from the flax, spices like the nutmeg, and many medicines. We have to consider, however, not the uses to which we put these seeds, but the way in which they are adapted for their own development.

It is bad for the seeds to start too near the mother plant, for they have no chance to grow. Every year we see hundreds of tiny maples starting up under our trees, in house and garden. What becomes of these vigorous little plants? They grow but a little while, there is no place for them in the world they have entered, the light, sun, nourishment are all taken from them by their bigger and stronger parents. Therefore the seeds who venture out further into the world and find places unoccupied by large plants have a better chance to live, and become in their turn the giants who crush out the young, weak life around them.

There are many ways in which this dispersion of seeds is accomplished. We have noticed in Chapter IX those seeds which are contained in edible fruits, attractive to birds and animals. Whenever we see a fruit, juicy, sweet and bright-

colored, we may be perfectly sure that Nature intends it to be eaten and that this process will only aid her purpose of planting as many seeds as widely as possible. We shall find that the seeds are hard and indigestible, or that they are protected by some indigestible part. Look at the blueberries, blackberries, strawberries, and raspberries that cover our New England fields in summer. We all know how hard the seeds are, and how they feel like little stones between our teeth. It does not hurt such seeds at all to be eaten by birds, but, on the contrary, the moisture and warmth to which they are subjected in the bird's stomach are favorable to speedy germination. The birds in their wide flights drop the undigested seeds far from the spot where they left the parent plant.

Many seeds will resist the action of water for a long time, so that they may be carried by rivers or ocean currents to places many miles distant from their starting point. Charles Darwin tried a series of experiments on immersing seeds in salt water to test their vitality after prolonged soaking. He found that many seeds germinated excellently after being under water for more than a month, and several after three months immersion. He was not satisfied with his experiments as an explanation of the carrying of seeds across wide reaches

of ocean, however, because there seemed to be no way of preventing the seeds from sinking.

He succeeded in proving that seeds might be carried by being swallowed by a fish, the fish, in turn, being gobbled by a heron. He writes, "I find that fish will greedily eat seeds of aquatic grasses, and that millet-seed put into a fish and given to a stork, and then voided, will germinate. So this is the nursery rhyme of 'This is the stick which beats the pig,' etc., etc."[1]

But before the seeds have acquired their hard, indigestible outer coat they would be destroyed by being eaten. They are protected from such a fate by the unattractive character of the fruit before it is ripe. We have to charge children not to eat apples until the seeds are black, for they, for some inscrutable reason, do not share the aversion of animals to the acid juices of a green apple. What the children have not sense enough to avoid, the birds leave severely alone. The robins know to a day when the cherries are ripe. Before maturity these fruits are hard, sour, and unattractive in color, but when the seeds are ripe they become sweet and juicy.

Some seeds have hairy coats, which prevent their being digested, like the seeds of a Rose-hip, and others are very bitter, like those of the orange.

[1] "Life and Letters of Charles Darwin." Vol. I, p. 416. Note.

In some juicy fruits, where the seeds themselves are soft, they are protected by a hard stone, as in all the stone fruits, the peach, cherry and plum. Here the inner wall of the ovary becomes hard and makes a thick wall about the seed, making a complete protection. In the apple the walls of the ovary harden into the little sharp bits that are apt to stick between one's teeth. These make the core indigestible, and it is for this reason rejected by animals, or passed through the body undigested.

We thus see that it is useful to the plant to have these attractive fruits eaten by birds and animals. But there is another class of creatures from which the fruit needs protection, the ants, snails, and beetles, which would devour the pulp and play no part in carrying the seeds.

If we shake a Raspberry bush and scatter the ripe fruit on the ground, we shall find, if we pass that way the next day, that the ants and other small deer have been having a feast. The fruit is sadly eaten, while that which we left on the bush remains fair and untouched. Why do not the ants climb the bush and regale themselves with the unplucked fruit? The shrub is well protected with a hedge of prickles, and no small creature can climb the stem. So is it, too, with the Blackberry and Rose, and many other plants are covered with thick, soft hairs, difficult to surmount.

A similar case is described in "Pflanzenleben" (II. p. 438):

"The fruits of the Rose, called hips, ripen in autumn, but do not fall off from their stalks when ripe. The seeds are in little hard nutlets, imbedded in the fleshy receptacle. The dispersion is aided by jays, thrushes and other birds, which eat the hips for food, digest the fleshy part, and void the nutlets undigested, more or less far from the parent plant. While these birds are welcome guests and are lured by the striking color of the Rose-hips, mice and other little rodents are in the highest degree unwelcome, for they gnaw the hidden nutlets, and quickly tear out their contents, the seeds. Against these bad guests the fruit should be fully protected, and so it is. The stems and branches up which the dangerous, little, gnawing creatures must make their way to the fruit, bristle with prickles which point their crooked sharp thorns downwards, and make it impossible for the mice to crawl up. In late autumn, when the mice come in from the fields to take up their winter quarters in the haunts of men, I have often plucked hips from my Rose-trees and placed them on the ground beneath the bushes at night. I always found them gnawed and destroyed in the morning, while the hips on the bushes remained unharmed."

There are a good many edible fruits, such as nuts, where the seeds are destroyed by being eaten. The coloring of these fruits is never attractive, but rather protective. While they are on the tree they are green and hardly to be distinguished from the leaves, and when they ripen and fall on the ground they become brown. We have to hunt to find the brown chestnuts, which are so nearly the color of the ground. They are protected, too, in various other ways, by a hard, bitter shell, like the walnut ; a prickly burr, like the chestnut (Fig. 19); or tough case, like the beechnut. There are so many that the most industrious squirrels will hardly find them all, and these must undoubtedly aid in the dispersion by dropping some of the nuts on the way to their holes.

When we come to the dispersion of inedible fruits we shall find that they travel in a great variety of ways.

Some seeds are so minute that they are scattered easily by the wind. The tall spikes of grasses that raise themselves above the matted leaves in every field have tiny, hard seeds that, when ripe, are scattered broadcast by every high wind. When the wind blows the ripe heads of the Poppy, the little seeds are shaken out of the holes under its spreading stigmas like pepper when we shake the pepper-box.

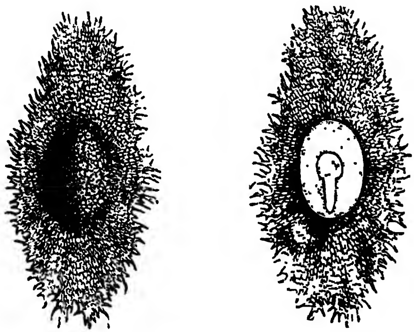
A large number of seeds are adapted to be carried by the wind by special developments of the

FIG. 31. ULMUS GLABRA. ("Pflanzenleben.")
1. Branch with staminato flowers. 2. Branch with fruit.

outer coat of the seed, or of some neighboring part of the flower.

Pick up a seed of Maple, or Ash, and you will see an outgrowth which is well termed a wing. By means of the wing it sails on a favoring breeze and is often gently dropped into a spot where it has a good chance to get sufficient sun and air.

The Elm seeds are surrounded by a flat wing, which answers the same purpose Fig. 31[2]. The



1 2

FIG. 32. ("Pflanzenleben.")

1. Cinchona seed. 2. In vertical section

Willow has seeds provided with silky hairs which make it fly fast and far. Let us take the commonest flower we can think of to illustrate this method of dispersion, the Dandelion. When the yellow disk has faded and the time of flowering is past, the green circle of bracts surrounding the flower closes tightly over the forming seeds (Fig.

33^4). Protected by this covering, they develop in safety, the beak of the ovary lengthens, and bears up with it the tuft of hairs, which is a modified calyx, and at last the protecting involucre bursts

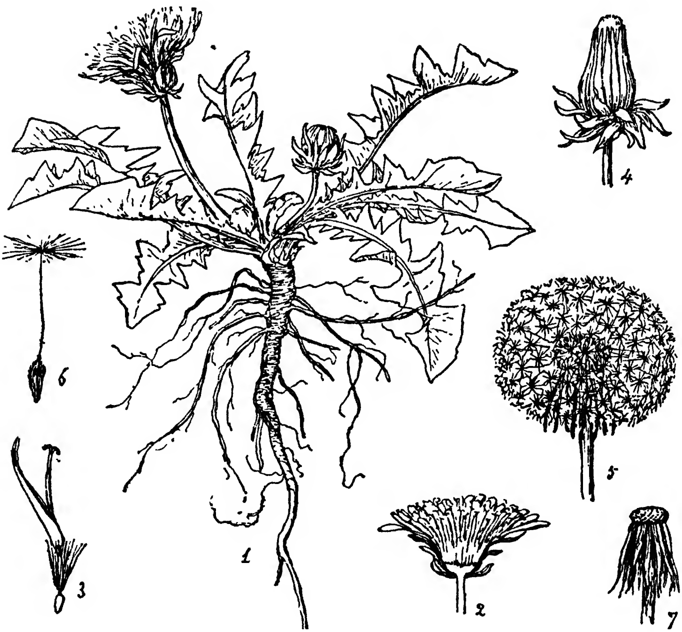


FIG 33 DANDELION

1. Whole plant 2 Section of head. 3. Single flower 4. Head after flowering 5. Head in fruit 6. Akene 7 Receptacle after the akenes have blown away

open, and there is the dainty head of fruits, (Fig. 33^5) ready for the first puff of wind to carry them

far and wide, or for some child passing that way to pick it and see "whether my mother wants me," thus innocently aiding in the dispersion planned by Nature.

There are hundreds of seeds formed on the same type as the Dandelion, some with the hairs belonging to the outer seed-coat, some to the outside of the ovary, some, like the Dandelion, to the calyx. The most important example of the hairs growing on the seed is in the cotton plant. The reason why this plant is useful to us, while other hairy seeds are not, is the fact that the fibres are twisted and thus hold together when woven. We see an example of a hairy seed in the Cinchona seed (Fig. 32).

Another way of dissemination is the forcible ejection of seeds from their capsules, sometimes to great distances from the parent plant. A friend told me that, having picked one autumn a number of branches of the *Hamamelis*, or Witch-Hazel, and placed them in water in her room, she was awakened one night by being violently bombarded with the seeds, which were thrown from the other side of the room with such force that it was like a small hail-storm. The Violet pod (Fig. 34) also possesses this property, and most of us have rejoiced in pinching the *Impatiens*, which has earned its name of Touch-me-not,

by the sudden violent bursting of its pods when touched.

Our common House-Geranium has hairy carpels, which split elastically upward away from the axis of the ovary when ripe. These seeds are a good example of an extremely curious contrivance for self-planting. The beak of the carpel is spirally coiled when dry, and ends in a long awn. On being placed on a damp surface, such as the moist earth in a flower-pot, the spiral begins to uncoil and this movement causes the end containing the seed to point downward towards the earth, while the long awn is pressed in a slanting direction against the ground, so that the whole carpel is raised in the form of an arch. The further uncoiling then acts like a corkscrew and pushes the seed into the ground. The fruit is covered with upward-pointing bristles, so that once pushed into the earth, it cannot be withdrawn. Thus the seed works gradually into the ground and is self-planted.

FIG. 34

One other important means of dispersion remains to be noted, the possession of prickles, barbs, or hooks, by the seeds, or seed-like fruits, which causes them to cling firmly to any foreign substance with which they are brought in contact.

A familiar illustration of this is the Burdock, out of which the children make bur-baskets. Everyone who has walked in the woods in late summer or fall must have suffered from coming in contact with such plants. Their names indicate their character, Beggar's Lice (*Cynoglossum Morisoni*), Tickseed (*Coreopsis*), Beggar-ticks (*Bidens frondosa*), and Stickseed (*Echinospermum*). I remember one walk in Middlesex Fells when, after a plunge through a small thicket, I found my dress a mass of little barbed nutlets, literally covered with thousands of seeds. It took me the remainder of the walk through the woods to pick off the troublesome things, and I could not help smiling to think how well the sly *Cynoglossum* had pressed me into its service, and caused the path for a distance of two miles to be strewn plentifully with its future offspring.

XIV.

THE HABITS OF INSECTS IN RELATION TO THE FERTILIZATION OF FLOWERS.

[1]Bees and various other insects must be directed by instinct to search flowers for nectar and pollen, as they act in this manner without instruction as soon as they emerge from the pupa state. Their instincts, however, are not of a specialized nature, for they visit many of the exotic flowers as readily as the endemic kinds, and they often search for nectar in flowers which do not secrete any; and they may be seen attempting to suck it out of nectaries of such length as cannot be reached by them. All kinds of bees and certain other insects usually visit the flowers of the same species as long as they can, before going to another species. This fact was observed by Aristotle with respect to the hive-bee more than 2000 years ago, and was noticed by Dobbs in a paper published in 1736 in the Philosophical Transactions. It may be observed by anyone, both with hive and humble-bees, in every

[1] "The Effects of Cross and Self Fertilization in the Vegetable Kingdom." By Charles Darwin. London, John Murray, Albermarle Street, 1876. p. 415.

flower-garden; not that the habit is invariably followed. . . .

[2]That insects should visit the flowers of the same species as long as they can, is of great importance to the plant, as it favors the cross-fertilization of distinct individuals of the same species; but no one will suppose that insects act in this manner for the good of the plant. The cause probably lies in insects being thus enabled to work quicker. They have just learned how to stand in the best position on the flower, and how far and in what direction to insert their proboscces. They act on the same principle as does an artificer who has to make half a dozen engines, and who saves time by making consecutively each wheel and part for all of them. Insects, or at least bees, seem much influenced by habit in all their manifold operations; and we shall presently see that this holds good in their felonious practice of biting holes through the corolla.

It is a curious question how bees recognize the flowers of the same species. That the colored corolla is the chief guide cannot be doubted. On a fine day, when hive-bees were incessantly visiting the little blue flowers of *Lobelia erinus*, I cut off all the petals of some, and only the lower striped petals of others, and these flowers were not

[2] Page 419.

once again sucked by the bees, although some actually crawled over them. The removal of the two little upper petals alone made no difference in their visits. Mr. J. Anderson likewise states that when he removed the corollas of the *Calceolaria*, bees never visited the flowers. On the other hand, in some large masses of *Geranium phæum* which had escaped out of a garden, I observed the unusual fact of the flowers continuing to secrete an abundance of nectar after all their petals had fallen off; and the flowers in this state were still visited by humble-bees. But the bees might have learnt that these flowers, with all their petals lost, were still worth visiting, by finding nectar in those with only one or two lost. The color alone of the corolla serves as an approximate guide; thus I watched for some time humble-bees which were visiting exclusively plants of the white-flowered *Spiranthes autumnalis*, growing on short turf at a considerable distance apart; and these bees often flew within a few inches of several other plants with white flowers, and then, without further examination, passed onwards in search of the Spiranthes. . . .

That the color of the flower is not the sole guide, is clearly shown in the six cases above given [1]

[1] Humble and hive-bees are good botanists, for they know that varieties may differ widely in the color of their flowers and yet belong to

of bees which repeatedly passed in a direct line from one variety to another of the same species, although they bore very differently colored flowers. I observed also bees flying in a straight line from one clump of a yellow-flowered *Œnothera* to every other clump of the same plant in the garden, without turning an inch from their course to plants of *Eschscholtzia* and others with yellow flowers which lay only a foot or two on either side. In these cases the bees knew the position of each plant in the garden perfectly well, as we may infer by the directness of their flight; so that they were guided by experience and memory. But how did they discover at first that the varieties with differently colored flowers belonged to the same species? Improbable as it may appear, they seem, at least sometimes, to recognize plants even from a distance by their general aspect, in the same manner as we should do. On three occasions I observed humble-bees flying in a perfectly straight line from a tall Larkspur which was in full flower to another plant of the same species at a distance

the same species. I have repeatedly seen humble-bees flying straight from a plant of the ordinary red *Dictamnus fraxinella* to a white variety; from one to another very differently colored variety of *Delphinium consolida* (Larkspur) and of *Primula veris;* from a dark purple to a bright yellow variety of *Viola tricolor* (Pansy), and with two species of *Papaver* (Poppy); from one variety to another which differed much in color. p. 416.

of fifteen yards, which had not as yet a single flower open, and on which the buds only showed a faint tinge of blue. Here neither odor nor the memory of former visits could have come into play, and the tinge of blue was so faint that it would hardly have served as a guide.

The conspicuousness of the corolla does not suffice to induce repeated visits from insects, unless nectar is at the same time secreted, together, perhaps, with some odor emitted. I watched for a fortnight many times daily a wall covered with *Linaria cymbalaria* in full flower, and never saw a bee even looking at one. There was then a very hot day, and suddenly many bees were industriously at work on the flowers. It appears that a certain degree of heat is necessary for the secretion of nectar; for I observed with *Lobelia erinus* that if the sun ceased to shine for only half an hour, the visits of the bees slackened and soon ceased. . . . Now how did so many bees discover at once that the flowers were secreting nectar? I presume that it must have been by their odor, and that as soon as a few bees began to suck the flowers, others of the same and of different kinds observed the fact and profited by it. We shall presently see, when we treat of the perforation of the corolla, that bees are fully capable of profiting by the labor of other species. Memory also comes into play, for, as

already remarked, bees know the position of each clump of flowers in a garden. I have repeatedly seen them passing round a corner, but otherwise in as straight a line as possible, from one plant of *Fraxinella* and of *Linaria* to another and distant one of the same species; although, owing to the intervention of other plants, the two were not in sight of each other. . . .

[1] The extraordinary industry of bees and the number of flowers which they visit within a short time, so that each flower is visited repeatedly, must greatly increase the chance of each receiving pollen from a distinct plant. When the nectar is in any way hidden, bees cannot tell without inserting their proboscces whether it has lately been exhausted by other bees, and this, as remarked in a former chapter, forces them to visit many more flowers than they otherwise would, but they endeavor to lose as little time as they can Thus, in flowers having several nectaries, if they find one dry they do not try the others, but, as I have often observed, pass on to another flower. They work so industriously and effectually, that even in the case of social plants, of which hundreds of thousands grow together, as with the several kinds of Heath, every single flower is visited, of which evidence will presently be given. They lose no time

[1] Page 424.

and fly very quickly from plant to plant, but I do not know the rate at which hive-bees fly. Humble-bees fly at the rate of ten miles an hour, as I was able to ascertain in the case of the males from their curious habit of calling at certain fixed points, which made it easy to measure the time taken in passing from one place to another. . . .

[1] *Perforation of the Corolla by Bees.* I have already alluded to bees biting holes in the flowers for the sake of obtaining the nectar. They often act in this manner, both with endemic and exotic species, in many parts of Europe, in the United States, and in the Himalayas ; and therefore probably in all parts of the world. The plants, the fertilization of which actually depends on insects entering the flowers, will fail to produce seed when their nectar is stolen from the outside ; and even with those species which are capable of fertilizing themselves without any aid, there can be no cross-fertilization, and this, as we know, is a serious evil in most cases. The extent to which humble-bees carry on the practice of biting holes is surprising. A remarkable case was observed by me near Bournemouth, where there were formerly extensive heaths. I took a long walk and every now and then gathered a twig of *Erica tetralix.* When I had got a handful all the flowers were examined

[1] Page 425.

through a lens. This process was repeated many times, but, though many hundreds were examined, I did not succeed in finding a single flower which had not been perforated. Humble-bees were at the same time sucking the flowers through these perforations. On the following day a large number of flowers were examined on another heath with the same result, but here hive-bees were sucking through the holes. This case is all the more remarkable, as the innumerable holes had been made within a fortnight, for before that time I saw the bees everywhere sucking in the proper manner at the mouths of the corolla. . . .

[1] As far as I have seen, it is always humble-bees which first bite the holes, and they are well-fitted for the work by possessing powerful mandibles; but hive-bees afterwards profit by the holes thus made.

[2] The evidence derivable from the relations of bees to flowers is probably sufficient to satisfy most minds that bees are capable of distinguishing colors, but the fact had not been proved by any conclusive experiments. I therefore tried the following: If you bring a bee to some honey, she

[1] Page 427.

[2] "Flowers, Fruits and Leaves." By Sir John Lubbock. London, Macmillan & Co., 1886, p. 11.

feeds quietly, goes back to the hive, stores away her honey, and returns, with or without companions, for another supply. Each visit occupies about six minutes, so that there are about ten in an hour, and about a hundred in a day. I may add that in this respect the habits of wasps are very similar, and that they appear to be quite as industrious as bees.

I once tested this by training a bee and a wasp to come for some honey, and then timing them through a whole day. Knowing they would be early I went into my study a few minutes after 4 in the morning, but the wasp was already at work, and continued without a moment's intermission until 7.46 in the evening, working without a moment's rest for nearly sixteen hours, and making no less than 116 visits to the honey. The bee began at 5.45 A.M., or somewhat later than the wasp, and left off also rather earlier. . . .

This, however, was in autumn; in summer they make more overtime, and work on even late in the evening.

In fine weather bees visit often more than twenty flowers in a minute, and so carefully do they economize the sunny hours, that in flowers with several nectaries, if they find one dry, they do not waste time by examining the others on the same plant. Mr. Darwin watched carefully certain flowers, and

satisfied himself that each one was visited by bees at least thirty times in a day. The result is, that even where flowers are very numerous — as, for instance, on heathy plains and clover fields — every one is visited during the day. Mr. Darwin has carefully examined a large number of flowers in such cases, and found that every single one had been visited by bees.

In order to test the power of bees to appreciate color, I placed some honey on a slip of glass and put the glass on colored paper. For instance, I put some honey in this manner on a piece of blue paper, and when a bee had made several journeys, and thus become accustomed to the blue color, I placed some more honey, in the same manner, on orange paper about a foot away. Then, during one of the absences of the bee, I transposed the two colors, leaving the honey in the same place as before. The bee returned as usual to the place where she had been accustomed to find the honey; but, though it was still there, she did not alight, but paused for a moment, and then dashed straight away to the blue paper. No one who saw my bee at that moment could have had the slightest doubt of her power of distinguishing blue from orange.

Again, having accustomed a bee to come to honey on blue paper, I ranged in a row other supplies of honey on glass slips placed over paper of

other colors, yellow, orange, red, green, black and white. Then I continually transposed the colored paper, leaving the honey on the same spots ; but the bee always flew to the blue paper, wherever it might be. Bees appear, fortunately, to prefer the same colors as we do. On the contrary, flowers of a livid yellow, or fleshy color, are most attractive to flies ; and, moreover, while bees are attracted by odors which are also agreeable to us, flies, as might naturally be expected from the habits of their larvæ, prefer some which to us seem anything but pleasant.

XV.

THE COLORS OF FLOWERS A MEANS OF ATTRACTING INSECTS.[1]

SINCE contrasting colors quickly catch the eye even at a distance, plants make use of bright colors to attract the flying insects and show them where to find the flowers. As green is the most common background for flowers, we most frequently find in flowers the colors that contrast best with green. Of these, white occurs most often, next comes yellow, red, blue and violet, and last brown.

It is most frequently the corolla that displays the contrasting color, and this color is most prominent on the side that is turned toward the flying insect. If the flower is pendulous and has a cup-shaped or a bell-shaped corolla, the insect in flying past would not see the inside of the flower, so it is the outside that has the brightest coloring. On the contrary, if the flower is star-shaped or saucer-shaped, the inside of the corolla is the more brightly colored. . . .

[1] Condensed from the German of Kerner von Marilaun, by Miss A. M. Mitchell. "Pflanzenleben," Vol II, p. 178.

In some plants, the duty of attracting insects is assumed by the calyx. Thus, in the Anemone and the Globe flower (*Trollius*), instead of a green calyx, we find a calyx resembling a corolla in form

FIG 35. CORNUS FLORIDA. ("Pflanzenleben.")

and coloring, while the true corolla is either small and inconspicuous or wanting.

Less frequently it is the anthers that denote the location of the nectar and the pollen. In the

Willows, both the calyx and corolla are wanting, but the bright colored anthers in the closely packed catkins are sure to attract the attention. In a limited number of species, of which a familiar example is the Meadow-rue (*Thalictrum*), the filaments display the contrasting color.

It is quite common to find a cluster of inconspicuous flowers surrounded by highly colored bracts. This occurs in the flowering Dogwood (*Cornus florida*, Fig. 35), the Euphorbias and the large spathes of the Arum family.

If the flowers fall below a certain size, then even the most brilliant red or yellow would fail to attract the eye at a distance of more than a few feet. The number of single flowers that reach a size sufficient to attract the notice of flying insects is smaller than might be at first supposed. Only about a thousandth part of all the phanerogams have flowers with a diameter of more than 10 centimetres, and the majority of these are confined to the tropics.

. . . .

Therefore, instead of finding the flowers growing singly, we more often find them variously united in heads or clusters. In this manner, a flower having a diameter of 5 or 6 millimetres, which would not be noticed a couple of feet away, is united with others into a cluster 16 or 18 centi-

metres in diameter, and noticeable at a long distance.

In many cases, only a portion of the cluster is devoted to the work of attracting insects. In the Alyssum, after the individual blossoms have matured, when the nectar has been exhausted and the time has come for the ripening of the fruit, the flowers do not wither and fall off, but the corolla continues to increase in size, the diameter becoming twice as great as at first. In the Hydrangea (Fig. 7[8]) and the Hobble-bush (*Viburnum*) we find a slightly different division of labor. Here the showy outer flowers of the cluster are devoted to the work of attracting insects, but produce neither stamens nor pistils, while the inner flowers of the cluster have both these organs, but are small and inconspicuous. In the Viburnum, the gardener has suppressed the fertile flowers, and so given us the Snowball bush of our gardens.

A curious effect is produced by the dense heads of a plant found among the mountains of New Zealand. This plant is known to botanists as *Haastia*, but its appearance has led the colonists to give it the name of "vegetable sheep." The minute white flowers are clustered in countless numbers into large hemispherical masses, one-half a meter in height and about one meter in diameter. At a distance this strange vegetable growth pre-

sents the appearance of a flock of sheep resting on the hill-side. . . .

In addition to the contrast in color between the leaves and the flowers, we often find contrasts in

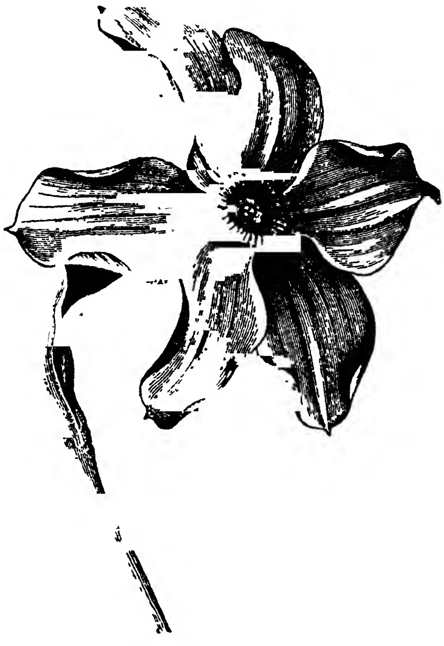


FIG. 36. NARCISSUS. ("Pflanzenleben")

the color of the flower itself. The stamens and corolla may be of contrasting colors, or, as in the *Hepatica*, we may find a white centre surrounded by a margin of a different color. The petals may

also be of different colors, as in the Pea ; or they may be variously marked with bands, stripes or spots, as in the Pansy, the Forget-me-not (*Myosotis*) and the *Narcissus* (Fig. 36). These stripes or dots are often of an additional benefit to the flower, in pointing out the direction of the nectary, and so indicating to the insect in just what part of the flower to look for nectar. Thus we see that the beautiful markings of the flowers, so pleasing to our eyes, were not placed there for our enjoyment alone, but are of practical use to the plant in ensuring the production of seed.

We may find the corolla contrasting in color with the calyx or the bracts. This occurs in the white calyx and the blood-red corolla of the Clerodendron, and, similarly, in the Melampyrum, we find yellow flowers contrasted with blue, red, or violet bracts.

Sometimes the corolla varies in color in different stages of its development. In the Clover, after the blossoms have matured, they do not fall off, but change to a dull brown, which forms a striking background to the pink and white flowers. In *Salix purpurea*, the anthers change from red to yellow, and finally to black.

. . . .

The zoölogists, as well as the botanists, claim that the insects, which carry the pollen from one

flower to another, have a highly developed sense of color, and that they will select flowers of one color and reject those of another with unerring accuracy. The honey-bee, for example, prefers blue or violet flowers, but sometimes visits yellow flowers, and also flowers of some shades of red; however, he carefully avoids flowers bordering on the scarlet and orange shades. It is possible that this rejection of certain colors by the bee may be due to a kind of color-blindness, similar to the color-blindness of human beings. If this is the case, it is probably true that the eye of the bee lacks those nerves that are acted upon and respond to the red rays.

The shades of red that are avoided by the bee are not shunned by the humming-birds; in fact, they seem to show a preference for that color. So in countries, where humming-birds abound, we find a large proportion of scarlet flowers.

In the dusk, such colors as scarlet, blue, and violet cannot be distinguished from the green of of the foliage. So the insects that fly in the evening and at night select flowers having a white or a bright yellow color. An occasional exception occurs in some flowers having a strong odor, which are visited by insects after dark, although their color would indicate that the contrary would be the case.

XVI.

EPOCHS IN THE HISTORY OF BOTANY.[1]

LINNÆUS seems to have been born a botanist. He writes in his diary that when he was four years old he went to a garden party with his father and heard the guests discussing the names and properties of plants; he listened carefully to all he heard, and "from that time never ceased harassing his father about the name, quality, and nature of every plant he met with," so that his father was sometimes quite put out of humour by the incessant questioning. However at last, when Dr. Rothmann took him into his house, he had opportunities of learning, and from that time he advanced so rapidly that he was soon beyond all his teachers.

In 1736, after meeting with many kind friends in his poverty, and making a journey to Lapland, which was paid for by the Stockholm Academy of Science, he went to Holland. Here he called on the celebrated Boerhaave, who with his usual good nature introduced him to a rich banker, named

[1] "A Short History of Natural Science." By Arabella B. Buckley. New York, D. Appleton & Co., 1890, p. 206.

Clifford, who was also a great botanist. This was the turning point in Linnæus's life. Mr. Clifford invited him to live with him, treated him like a son, and allowed him to make free use of his magnificent horticultural garden. He also sent him to England to procure rare plants, and gave him a liberal income. It was at this time that Linnæus is said to have been so overcome by the sight of the mass of golden bloom on the furze at Putney Heath, that he fell upon his knees and thanked God for having created a plant of such wondrous beauty. Linnæus continued with Mr. Clifford for some time, till his health began to fail, and he found besides that he had learnt all he could in this place, so he resolved to leave his kind friend and wander farther. Mr. Clifford seems to have been much hurt at his leaving, yet he continued his kindness to him through life.

Linnæus went to Leyden and Paris, and from there to Stockholm, where he practised as a physician, and at last he settled down as Professor of Medicine and Natural History at Upsala, where he founded a splendid botanical garden, which served as a model for many such gardens in other countries, such as the Jardin de Trianon in France, and Kew Gardens in England. His struggles with poverty were now over forever, and his fame as a botanist was spread all over the world. He used

to set out in the summer days with more than 200 pupils to collect plants and insects in the surrounding country, and many celebrated people came to Stockholm to attend Linnæus's "Excursions." Then as his pupils spread over the world he employed them to collect specimens of plants and animals from distant countries, and he himself worked incessantly to classify them into one great system.

Linnæus Gives Specific Names to Plants and Animals.—And now we must try to seize upon the chief points of Linnæus's work, in order to understand something of what he did for science, although it is quite impossible in a book of this kind to give even a sketch of his divisions of the animal and vegetable kingdoms. The first and greatest point of all was that he gave a second or specific name to every plant and animal. Before his time botanists had only given one name to a set of plants; calling all roses, for example, by the name *Rosa*, and then adding a description to show which particular kind of rose was meant. Thus, for instance, for the Dog-rose they were obliged to say *Rosa, sylvestris vulgaris, flore odorato incarnato*, that is, "common rose of the woods with a flesh-coloured sweet-scented flower." This, you will see, was extremely inconvenient; it was as if all the children in a family were called only

by their father's name, and you were obliged to describe each particular child every time you mentioned him; as "Smith with the dark hair," or "Smith with the long nose and short fingers," etc. A botanist named Rivinus had suggested in 1690 that two names should be given to plants, and Linnæus was the first to act upon this idea and to give a *specific*, or, as he called it, *trivial* name to each particular kind of plant, describing the plant at the same time so accurately that any one who found it could decide at once to what species it belonged. To accomplish this he classified all plants, chiefly according to the number and arrangement of their stamens and pistils (or the pollen-bearing and seed-bearing parts), and then he subdivided them by the character and position of their leaves and other parts. . . .

You will see that by this system it is always possible to find out easily to what part of the vegetable kingdom your plant belongs, and what its name is; and if, after you have traced its genus, there is no species which exactly agrees with yours, you then know that you have discovered a new species which has not been described before. Linnæus classified animals after this same plan, quadrupeds chiefly by their teeth, and birds by their beaks and feet, and after his system was complete, any one could discover the scientific name of a

plant or animal by exercising a little care and patience. This system is called the Linnæan or *artificial system*, because it only selects a few particular parts of a plant, so as to help you to look it out in a kind of dictionary. It tells you very little of the real or natural life of the plant, and often brings some very near together which are really very different. It is as if you classified people by some particular feature, such as those who had long hair, or short hair, dark or light, curly or straight. This might be very useful for recognizing them, but it would be quite artificial, and would tell you very little about their real relationship. Therefore this classification has now been partly set aside for another or *natural* classification, which Linnæus also suggested, only he thought it too difficult for ordinary people; and which was worked out by a French botanist named Jussieu, as we shall see by and by. But the Linnæan system is still extremely useful for finding the name of a plant or animal, and many people in the last century were led to study zoölogy and botany by the simplicity of the classifications of Linnæus. The other useful point in Linnæus's system was the accurate and precise terms he invented for describing plants. . . .

Linnæus was not a vigorous old man. The hard struggles of his youth and the immense work of

his after-life had worn him out, and at fifty-six he was obliged to ask the King of Sweden to let his son lecture sometimes in his place. With this help he continued to work at science till within two years of his death, when his mind became feeble. He died in 1778, loaded with honors and beloved and esteemed by the greatest men all over the world. His had been a noble life; enthusiastic and truth-loving, he had worked, even when he was poor, for science and not for wealth, and when he became famous and rich he helped his pupils as others had helped him, and lived simply and frugally till his death. Unlike Buffon, his private life was as pure as his public life was famous. Over the door of his room he placed the words "*Innocuè vivito, Numen adest*" ("Live innocently, God is present"), and he lived up to his motto. His study of nature had filled him with deep reverance and love for the Great Creator, and he used often to tell his friends how grateful he was to God for those gifts which had made his life so full of interest and delight. . . .

Natural System of Plants, Bernard and Antoine de Jussieu.[1] — Even while Linnæus was living, another botanist, Bernard de Jussieu (1699–1767), had begun to carry out his suggestion that plants should be classed by the agreement of all their

[1] "A Short History of Natural Science." p. 412.

observable characters, and not merely artificially by the number of their stamens. But Bernard did not publish his catalogue, and it was his nephew Antoine de Jussieu (1748–1836) who first published a book in which the plants were arranged according to the Natural System. It was Antoine who first sketched out roughly the characters of "Families or Natural Orders" as we have them now. He made 100 families from the plants then known, and though many more have been added since, yet a large number of those which he worked out have been permanently adopted. The Natural System obliges botanists to take into account every part of a plant before placing it in a family or order, and as it is often very difficult to determine which are the characters of most importance, there is a good deal of difference between the arrangements adopted by one botanist or by another. But though this is tiresome to pupils, it has been very useful in science, for it has served to bring out most clearly the way in which plants are related to each other, and the fact that in Nature there are not sharp distinctions between different kinds of plants, but that a particular species may be very closely allied in some of its characters to one family and in others to another, so that it is perhaps hardly too much to say that our great advance in botany in the present century has arisen from two

things — (1) from the attempt to classify plants according to their natural affinities ; and (2) from discoveries made with the microscope, begun by Grew and Malpighi in the seventeenth century, and carried to perfection in our day.

The great Swiss botanist Auguste Pyrame de Candolle (1778–1841) did a great deal to spread the Natural System by adopting it in his works, and also by modifying it in many ways ; and still further improvements have been made by the great Scotch botanist Robert Brown (1773–1858), and by Endlicher (1804–1849), and Lindley (1799-1865).

Goethe's Theory of the Metamorphosis or Transformation of Plants, 1790.—We have said that the study of the Natural System led botanists to observe more carefully the nature of plants and the manner in which they grow. One of the first men who threw any light upon the history of the growth of plants was the poet Goethe. Goethe had a deep love of Nature, as may be seen in many of his beautiful minor poems, and this love led him in the year 1780 to devote himself to the study of the anatomy of plants and animals.

When he turned his attention to botany he was very much struck with the power which plants have of transforming or changing the growth of their parts. For example, the common wild Rose in the hedges has a crown of pink petals, with

stamens and carpels in the centre ; but the garden Rose, which is nothing more than the wild Rose grown in a better soil, has lost the stamens and pistils, or rather has changed them into flower-leaves, so that the whole flower is one mass of petals, and rarely forms any seeds.

It is clear, therefore, said Goethe, that the stamens and pistil of a plant are nothing more nor less than flower-leaves transformed into a peculiar shape, so that they serve to form seeds, and to carry on the life of the plant. And this is true of all the different parts of the plants. Wherever you look in the vegetable kingdom, you will find that every part of a plant is nothing more than stem or leaves altered in various ways to suit the work they have to do. Thus the stem of a Geranium, the trunk of a tree, the twining stalk of the vine, the straw of Wheat, the runners of a Strawberry, and the fleshy potato, are all only different forms of stems and branches. Again, the two cotyledons of a seed which are well seen in the halves of a bean are but the first pair of leaves. From between them grows the stem, and out of this leaves of different forms, according to the peculiar species of plant.

Then, as the plant develops, come the buds of the flower, but these again are stems and leaves growing more thickly together, but altered and

adapted to new functions. We find in different plants every variety of flower from mere green leaf-like blossoms to the most gorgeous colors. The green leaves called sepals, which lie under the yellow petals in the Buttercup, are transformed into brilliantly colored petals in the Tulip, while in some cases, such as occasionally in White Clover, the whole flower, sepals, petals, pistil and stamens, has been known to be changed into little leaflets growing as if upon a branch.

For this reason gardeners find it possible to cultivate a plant so that it shall be all leaves and no flower, or, on the other hand, shall have a gorgeous flower while the leaves remain small and insignificant. And thus we are led to see that all the different parts of a plant are only peculiar transformations of simple stems and leaves.

This beautiful truth of the transformation or metamorphosis of plants we owe to the poet Goethe; for though Linnæus suggested it rather vaguely in some of his writings, and a botanist named Wolff seems also to have taught it in 1766, yet it was Goethe's essay on the "Metamorphosis of Plants," published in 1790, which first led naturalists to consider the question. Goethe's work was very little read at first, and he had great difficulty in finding a publisher for it, for it was thought that a poet could not know much of science; but

Auguste de Candolle, seeing what a new light Goethe's theory threw upon the study of plants, taught it in his works, and then it became gradually known as one of the greatest discoveries in modern botany.

Fertilization of Plants by Insects, Conrad Sprengel, 1750–1816.—Another equally important fact was established at this time by the German botanist Sprengel, who was the first to notice the wonderful connection between plants and insects, which Darwin, Hermann Müller, and others have worked out so minutely.

Christian Conrad Sprengel was Head-Master at Spandau in Brandenburg, but he became so wrapt up in his botanical studies that he was obliged to give up his office, and he lived in great poverty at Berlin, teaching languages and botany. He was so poor that he was not able to publish the second volume of his famous work on botany, and the publisher had not even given him a copy of the first volume for his own use. . . .

Structural and Physiological Botany, Robert Brown, 1773–1858.—The beautiful study of the relation between insects and flowers is more easy to understand, but certainly not more important, than the investigations into the structure and life of plants which have been carried on in the present century. Ever since the time of Mal-

pighi and Grew the improvement of microscopes and the examination of minute parts of plants had been progressing; and Mirbel (1776–1854) in France, and Moldenhauer (1766–1827) in Germany, together with many others, had greatly added to our knowledge of the structure of the cells and tissues of plants, the growth of stems, and the formation of seeds. Grew had already pointed out in 1672 that the outer coat of seeds has a little hole in it which he thought was for the purpose of letting the roots of the young plant grow out; and Mirbel in 1815 showed that when a young ovule, such as you will find in the ovary of a flower-bud, begins to grow it appears first as a little swelling made up of cells called the nucleus, growing on a short stalk, and that round this usually two coats gradually grow, one outside the other, while neither of them close quite round the nucleus but leave the opening which Grew had observed, and which had already been called the *micropyle*, or "little gate." It is, however, to the Scotch botanist, Robert Brown, that we owe the first complete explanation of the use of these different parts.

Robert Brown was the son of a minister at Montrose, and his first great step in botany was made when he went with Captain Flinders's expedition to Australia in 1801, and spent five months there, bringing back with him 4000 new species.

He then became conservator to Sir J. Banks's museum; and after the death of that eminent botanist he removed with the collection to the British Museum, where he received £350 a year, and a pension of £200 granted by Sir Robert Peel at Humboldt's request. A whole volume might be written of the additions which he made to botanical knowledge. . . .

Protoplasm, Hugo von Mohl, 1805–1872.[1]— The microscope had now revealed the history of some of the most delicate structures of plants, but one question remained unanswered, namely, What is the living, active matter which forms the cells, the tissues, and the fibres? The answer to this question was found in the year 1853 by the German botanist, Hugo von Mohl, when he showed that the young cells of plants are filled with a thick semi-fluid substance full of innumerable white granules and that, as the cell expands, these granules flow in streams from the centre to the circumference of the cell in never-ceasing activity.

We find this semi-fluid living matter equally in the embryo-sac of the young ovule and in all the cells of a young plant; and from it is formed that inert or dead matter which composes the cell wall; and, because it is the simplest form of vitality known to us, and out of it all the life of the plant

[1] "A Short History of Natural Science." p. 420.

springs, Von Mohl called it *Protoplasm*, or the *first formative material.*

Chemists have now shown that this living active protoplasm is composed chiefly of the four elements — hydrogen, oxygen, nitrogen, and carbon, and plants have the power of manufacturing it out of the non-living matter in the air and soil in which they grow. What this power is we do not know, and though the life in our own bodies and in that of all animals is supported by this same kind of living matter we cannot manufacture it; we, and all the animals, can only obtain it by feeding on plants, or on other animals which are vegetable feeders, and which therefore have had their food prepared for them.

Geographical and Economic Botany, Sir W. Hooker, 1785–1865. — Thus, by means of microscopic botany, our knowledge of the life of plants has been increased enormously in the present century; but it would not be fair to close this subject without speaking of the equally great advances in the study of the distribution of plants over the globe, and of their use to man. As far as England is concerned we owe much on this account to Sir William Hooker (1785–1865), who spent his life and a large part of his private fortune in encouraging the collection of plants all over the world, and in founding the Museums and Herba-

rium of Kew Gardens. He also exerted his influence largely in persuading the Government, both here and in the Colonies, to publish the Floras of the different districts, so that we now have a fairly accurate account of the plants of all the English possessions, and of the special homes or habits of different species, and this work has been carried on most effectively by his son, the present Sir Joseph Hooker.

Any botanist who now wishes to study the history of plants has means placed at his disposal, for which Gesner, Grew, Malpighi, and Linnæus longed in vain, and new observations are being added daily which should tempt all young minds to learn something of a science at once so beautiful and so accessible to every one who cares to turn his attention to it, moreover, the theory of evolution, which has been worked out in the last half of this century, has given quite a new interest to the study of every living thing, so that all these facilities ought to lead to a much more general knowledge than exists at present, both as to the use of plants in our daily life, and of their wonderful beauty.

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